THE EFFECT OF ULTRA-VIOLET RADIATION UPON HIGHER PLANTS[1]

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Introduction

The sterilizing action of ultra-violet radiation has been known for over fifty years. Downs and Blunt in 1877, working with putrefying material, were the first to discover it. Since then there have been many workers in this field, and to-day ultra-violet sterilization is a more or less common practice.

At present, work with ultra-violet rays is carried on along two different lines. One line deals with the effects produced in higher animals and man with particular reference to the depth of penetration of the rays and to the changes produced within individual cells. The other line deals with the effects produced in plants. Little work was done in the latter subject until 1911 when Kluyver studied the effect on plants of a long-continued raying with an ultra-violet lamp. From then until 1918 the subject received little attention. Since then, however, it has taken on a fresh impetus, and to-day there are many people working in that field. At the present time it is generally known that raying with an unscreened quartz mercury lamp causes injury due to the presence of the short rays. The important line of research now is to determine the effects of the longer ultra-violet rays on the different groups of plants, and this can be done only by the use of specific screens to eliminate certain rays.

Under favorable conditions the spectrum of sunlight contains rays as short as 291 μμ. Thus if a mercury vapor lamp is screened to absorb all rays shorter than 291 μμ, the same type of rays penetrate as are found in sunlight, the only difference being that

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the ultra-violet rays are much more intense, since the atmosphere screens out much of this group of rays originally in sunlight.

History

THE EFFECT OF ULTRA-VIOLET RADIATION ON LOWER ORGANISMS

Many articles have been written on the effect of ultra-violet rays on bacteria. Potthoff ('20) found that a suspension of bacteria 3½ mm. thick placed 15½ cm. from the light gave the following results.

LENGTH OF TIME NECESSARY FOR THE DESTRUCTION OF BACTERIA

	Spores	Vegetative cells
B. anthracis	5 minutes	15 seconds
B. subtilis	9 minutes	2 minutes
B. mesentericus	5 minutes	1 minute

In pigmented forms a short exposure inhibited the production of pigment, but upon repeated short exposures the pigment again appeared.

Mashimo ('19) found that the rays most effective in the destruction of bacteria were those between 295 and 186 μμ. He proved this by using in a quartz spectrograph a culture of bacteria instead of a photographic plate and noticing the region where no growth appeared.

Bazzoni ('14) found that the destructive power of ultra-violet radiation in relation to bacteria increased rapidly with a decrease in wave length, but that this effect was in some way dependent upon association with longer wave lengths. Wave lengths of from 220 to 225 μμ killed the bacteria after several hours, while the same intensity of light containing full radiation destroyed them very rapidly.

Burge ('17) has proved that ultra-violet rays kill living cells such as bacteria, not by destroying the intra-cellular enzymes but by coagulating the protoplasm. For his work he used bacteria that liquefy gelatin and found that the organisms killed by ultra-violet when ground with sand produced as much liquefaction as ground living organisms.

Green ('97) found that the destruction of diastase in a leaf was less than in an extract of malt or saliva and concluded that

either the chlorophyll or the proteins of the protoplasm must act as a screen absorbing the injurious rays.

Tanner and Ryder ('23) have found that yeast cells are almost as susceptible to ultra-violet radiation as bacteria, although pigmented yeasts are more resistant than white ones.

Nadson and Philippov ('28) used a Bach model of a quartz mercury vapor lamp giving rays as short as 220 μμ. Twenty-four-hour cultures of *Saccharomyces* and *Mucor* of different species on nutrient agar were rayed at thirty cm. from the light for ten to twenty minutes. For raying, the cover of the petri dish was removed and replaced by a piece of heavy glass with a circular opening in the center. After several days the region where there was no glass was devoid of growth, but just at the edge of the opening where only the slanting ultra-violet rays and hence the long ones were received, there was a marked increase in growth. Growth under the glass was normal. With yeast, not only increased, but abnormal, budding was noticed in the region of increased growth. With some fungi, asexual reproduction was increased while with others it was the sexual.

Larger organisms have been used for determining the effect of ultra-violet radiation on individual cells. Barr and Bovie ('23) used amoebae that had been cleared through starvation. They found that after an exposure of three-fourths of a second the amoebae ceased to move and after an exposure of one minute they were killed. At first the edge of the organism was irregular, but in a few seconds it became smooth by swelling. If irradiated for three to four minutes the animal swelled and clear spaces appeared between masses of protoplasm. Soon, however, crenulations were present about the border of the organism, giving the appearance of a loss of solution from the inside.

Tshuhotine ('23) thinks the rays first affect the plasma membrane, increasing permeability by coagulating the colloids. Then the surrounding medium enters and precipitates the protein colloids in the cytoplasm which surrounds the colloid particles of lecithin. Soon the base, coline, is formed which increases decomposition, giving OH ions which promote imbibitional swelling of the protein colloids of the cytoplasm until the cell is completely decomposed.

Brooks ('26) found that the shorter the rays, the greater the amount of 2,- 6,-dibromo phenol indophenol penetrating cells of *Valonia*.

THE EFFECT OF ULTRA-VIOLET RAYS UPON HIGHER PLANTS

Bailey ('94) was the first to notice the harmful effect of light on plants. He used an electric arc light and found that if a piece of glass were placed between the light and the plant the injurious effects were modified. He found lettuce and radishes very sensitive to the arc light. A few hours raying caused leaves of *Coleus* to become shiny and lose their purple color when that color was present only in the upper epidermis. When cross-sections of the leaves were examined, the epidermis was found to be collapsed and opaque, coloring the leaf brown. Professor Rowlee, working with Bailey, concluded that the palisade tissue absorbs a large amount of water from the epidermis, due to greater protoplasmic activity, and the epidermis thus emptied collapses.

The next person to do any extensive work on plants was Kluyver ('11), who, using a quartz mercury lamp giving rays of 230 μμ and shorter, gave the plants one long exposure. He verified Bailey's results as to the injury produced in higher plants and its modification by using a screen of thick glass. Only the epidermis of leaves was found to be affected, but in roots and stems the injury was deeper. Anthocyanin was again found to be decomposed by the short rays which do not penetrate. The longer rays were found to have no effect on anthocyanin.

Ursprung and Blum ('17) used a new method for determining injury. After raying plants the desired time the cells were plasmolyzed in sugar solution and then deplasmolyzed if possible in clear water. The less the injury the greater was the per cent deplasmolyzed in water. Epidermis and cuticle were found to exert a little protection. Usually cells containing chlorophyll were more resistant than those lacking it. Diatoms were found very susceptible, due to the large amount of silica in their walls.

Stoklasa ('11) found that a long exposure to ultra-violet radiation injured the epidermal cells but did not harm the chlorophyll in adjacent cells. Etiolated seedlings turned green in two hours

upon exposure to rays of from 400 to 300 μμ, while it took six hours to produce the same result in sunlight.

Schanz ('20) found that when the rays below 320 μμ were cut off the larger part of the red color disappeared from red-leaved lettuce. In like manner he caused the leaves of copper beech to become green.

Sheard and Higgins ('27) reported the effect of ultra-violet radiation on germination and growth of seeds. They used an unscreened quartz mercury lamp and screens of ultra glass, vita glass, and ordinary glass. In general they found that wave lengths of 270–320 μμ delayed the time and lessened the rate of growth, probably because of changes which carried to their extreme eventuate in the coagulation of the seed albumin. Rays of 320–390 μμ were particularly effective in promoting growth. When seedlings of lettuce, radish, and turnip were irradiated one, two, five, and ten minutes, those which normally germinate and grow in darkness showed most rapid germination and best growth when not rayed. Minimum growth was found in seedlings grown in diffused light. Radiation of these seedlings for two to three minutes by a quartz lamp accelerated the germination and subsequent growth as compared with non-rayed seedlings under similar conditions. Thus they state that raying with the near ultra-violet region aids germination and growth of a cell or normal functioning of an organism which is kept under unphysiologic environment.

Russell and Russell ('27), using a Hewittic mercury vapor lamp, found that when etiolated mustard seedlings were given short daily exposures to ultra-violet rays, dwarfing resulted in direct proportion to the length of exposure. Some chlorophyll appeared in all rayed seedlings. In seedlings grown under normal daylight conditions the dwarfing was not as great.

Dane ('27) found that soybeans irradiated by ultra-violet rays were dwarfed and the leaf and stem tissue brittle and stiff. Stems of irradiated plants were 1½ times as great in diameter as those of control plants. Rayed stems were hollow and showed reduction in medullary rays, the meristematic tissue thus remaining active for a much longer time than that in control plants. The ordinary parenchymatous cells of the medullary rays had developed into xylem and phloem.

Beeskow ('27) found that a daily irradiation of more than ½ minute caused injury to soybeans, but that irradiation of ½ minute caused no injury and might stimulate growth. When corn plants were rayed they showed an increased calcium and phosphorus content.

McCrea ('27) grew *Digitalis purpurea* to the ten-leaf stage in a greenhouse glassed with vita glass. She found greater growth and darker color than in control plants. The plants were then put outdoors and when cuttings were taken in August and September, the rayed plants were found to contain an increased amount of digitalin.

Delf and Ritson (Delf, Ritson, and Westbrook, '27) irradiated *Pelargonium*, *Coleus*, *Fuchsia*, *Abutilon*, *Salvia*, and *Trifolium* for various lengths of time and found retarded growth, delayed germination, retarded flower formation, and leaf fall. In addition there was a loss of anthocyanin by *Coleus* and in many cases a deeper green color produced in *Coleus* and other plants. Six-weeks-old seedlings of *Trifolium* when rayed one-half minute daily showed increased growth.

Westbrook (Delf, Ritson, and Westbrook, '27) used different lengths of days in addition to short exposures to ultra-violet radiation. In all cases injury was greater the shorter the day. The injury consisted in the development of thinner leaves with more compact mesophyll and smaller and fewer air-spaces, reduction of mechanical tissue, and collapse of the cells of the upper epidermis followed by a withdrawal of the chloroplastids from the upper ends of the palisade cells.

Tsuji ('18) obtained increased growth and a higher percentage of sugar in sugar cane grown in sunlight and rayed daily with a weak ultra-violet lamp. When pineapples were grown in sunlight plus a daily raying of forty minutes, the pineapples were sweeter, juicier, and larger than normal. When banana leaves and stalks were exposed to ultra-violet rays after being cut they kept fresh longer than similar leaves and stalks not rayed.

Clement ('26) has found that apples rayed for three hours showed a slight yellowing of the green side, and that when these apples were stored the rayed sides did not regain their green color but remained turgid longer than those not rayed.

Nadson and Rochline-Gleichgerwicht ('28), using a Bach model of an ultra-violet lamp emitting rays down to 220 μμ, have found that ultra-violet rays cause crystals of calcium oxalate to form in the cells of *Elodea densa*, *Elodea canadensis*, and *Pterygophyllum hepaticaefolium*. These plants were barely covered with water and placed thirty cm. away from the lamp for ten to thirty minutes. The crystals began as small granules, with a chloroplast often as the center, and increased to good size. After two to four days they dissolved simultaneously with the death of the cell. If the cells were treated with a narcotic before raying no crystals were formed.

THE EFFECT OF ULTRA-VIOLET RADIATION UPON ORGANIC MATERIALS

Calabek ('27) determined the effect of ultra-violet rays upon the swelling of biocolloids such as agar. When agar discs were rayed a marked decrease in swelling resulted. It was found that the effect of raying could be preserved in dry agar for several months even if the agar were redissolved. As a result the hypothesis was advanced that the effect of ultra-violet rays upon plants is due to a lowering of the swelling capacity of protoplasm and cell wall in the upper cellular layers of the plant.

Hess ('26) and others have found that when foods are rayed they are rendered rickets-protective. In vegetable foods phytosterol is activated while in animal foods it is the colesterol that is acted upon.

THE PENETRATION OF ULTRA-VIOLET RAYS

Several authors including Henri ('12) have found that the depth of penetration of the shorter ultra-violet rays through the skin is not more than .1 mm. However, for this work dead skin was used.

Macht, Anderson, and Bell ('28), using living anesthetized animals, have found that with an exposure of one minute ultra-violet rays as short as 302 μμ penetrate through living skin that is more than .1 mm. in thickness. When an exposure of two minutes was given rays as short as 280 μμ passed through. They then tested the penetration of rays into the peritoneal cavity of

rabbits and found that with an exposure of two minutes, rays as short as 313 μμ penetrated into the cavity. Next they compared the penetration of living skin with that of dead skin and found the former much more penetrable. When the dead skin was treated with a lipoid solvent it became as transparent to ultra-violet rays as living skin. The pigment in the skin of a negro was found to absorb almost all the short rays. The same result was obtained by injecting a rabbit intravenously with 1 per cent eosin solution.

Statement of the Problem

The problem in this paper is to determine the effect of ultra-violet light as a whole on higher plants, and whether the longer ultra-violet rays stimulate growth in higher plants.

Materials and Methods

EXPERIMENTAL

The lamp used for this work was an air-cooled Uviarc quartz lamp from the Burdick Cabinet Co. In the experiments designated as Series I this lamp was used without a screen of any kind. When used in this way the rays given off range from 578 to 200 μμ (5780 A. U.–2000 A. U.) (fig. 1).

When a screen of vita glass from the Hires Turner Glass Co. was interposed between the light and the plants the rays had a range of 578–289 μμ (5780 A.U.–2894 A.U.). The experiments using this screen constituted Series II.

A screen of quartz-lite glass from the American Window Glass Co. interposed between the light and the plant permits the passage of rays ranging from 578 to 313 μμ (5780 A.U.–3136 A.U.). Experiments using this glass are described in Series III.

The ultra-violet rays produced by a quartz mercury lamp may be divided into two groups, first, the abiotic rays (short rays), with wave lengths ranging from 185 to 290 μμ, which are reducing rays and hence killing rays, second, the biological rays (long rays) which range from 290 to 400 μμ. These are oxidizing rays and hence stimulating. The abiotic rays being very readily absorbed by the atmosphere are never present in sunlight when it reaches the earth, and were essentially eliminated where either of the

glass screens was used. The lamp was used at 50 and at 100 inches from the plant both with and without screens.

Although the atmosphere between the lamp and the plant absorbs some of the short rays, the distance of 100 inches is not sufficient to absorb all the short rays, and 50 inches without a screen allows a large percentage of the short rays to reach the plants. When a lamp screened by vita glass is used at a distance of 50 inches from the plants most of the short rays are absorbed, but none of the long ones. The same screen used at 100 inches

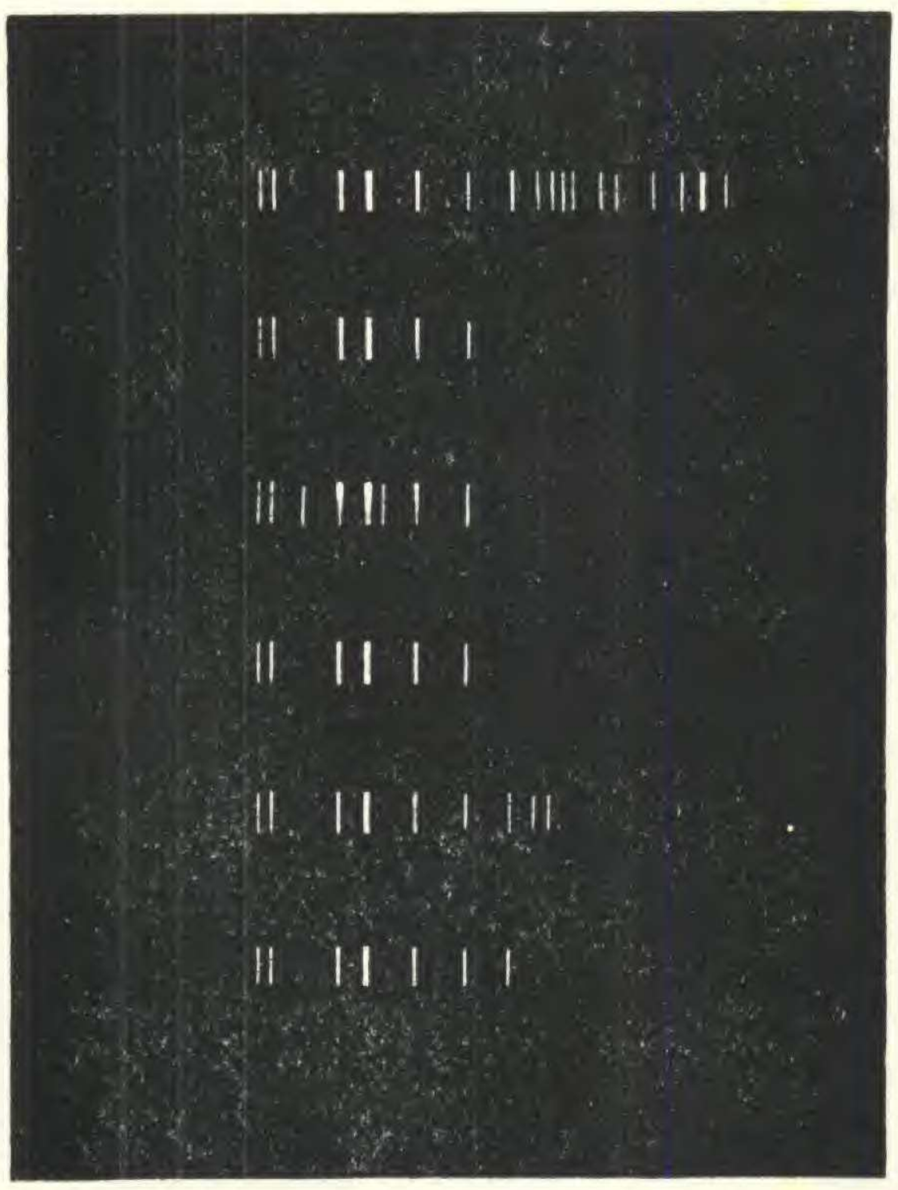

Fig. 1. Showing the spectrum of the different glasses.

from the plants allows only a large percentage of the long rays to reach the plants. When a screen of quartz-lite glass is used instead of vita glass, plants at a distance of 50 inches receive all the long rays and no short ones. The same screen at 100 inches allows only a part of the long rays to reach the plants.

Except for one group of experiments mentioned later the exposure began with 30 seconds the first day and each day was increased that amount. All plants under experiment were moved about each week in the greenhouse to eliminate all differences in environmental conditions.

The plants used were as follows: *Lactuca sativa* L. var. "Black-seeded Forcing"; *Raphanus sativus* L. var. "Early Scarlet Turnip White Tip"; *Cucumis sativus* L. var. "Improved Green Hybrid"; *Ipomoea Batatas* Poir.; *Phaseolus vulgaris* L. var. "Stringless Green Pod"; *Nicotiana Tabacum* L.; *Coleus Blumei* Benth. var. *Verschaffeltii* Lem. and vars. "Spotted Gem," "Defiance" and "Trailing Queen"; *Bryophyllum pinnatum* Kurz.; *Zea Mays* L. var. "Stowell's Evergreen."

Cuttings of *Ipomoea*, *Coleus*, and *Bryophyllum* were made and rooted in sand. They were then planted in rich potting soil in 3- and 4-inch pots. As soon as the plants had recovered from transplanting they were put under the conditions of the experiments. Seeds of *Raphanus*, *Lactuca*, *Cucumis*, and *Nicotiana* were sown in flats. As soon as the plants appeared above ground they were transplanted to 3-inch pots and put under experiment. Seeds of *Zea Mays* and *Phaseolus* were germinated between moist filter-paper and planted in 3-inch pots. All plants when not being rayed were kept under usual greenhouse conditions. A record was kept of the humidity and temperature.

ANATOMICAL METHODS

At the end of four weeks samples of the leaves of the plants rayed without a screen were taken for anatomical study. At the end of eight weeks samples of leaves and stems of all plants were taken for the same purpose. Care was taken in the sampling to take portions which were in corresponding positions on the plants and otherwise as nearly equivalent as possible.

The leaves and smaller stems were killed in medium chromo-acetic killing fluid and imbedded in paraffin. The larger stems were cut free-hand while fresh. Two stains were used: Haidenhain's Iron Haematoxylin and Safranin-Delafield's Haematoxylin.

PHYSIOLOGICAL METHODS

The rate of chlorophyll decomposition under the different screens, in sunlight, and in diffused light was tested, using an 80 per cent alcoholic solution of chlorophyll in vitreosil test-tubes.

The P_H of rayed and control plants in Series I was determined by the colorimetric method. The plant material was pressed in

a mortar and filtered through cotton. Then after diluting 1 to 10 with distilled water the chlorophyll was removed by filtration through an atmometer cup. The indicator was then added to the diluted juice freed from chlorophyll and the result compared with standard tubes.

Starch Storage.—Stem sections were made from fresh material of *Coleus* and *Phaseolus* in the different groups. These were stained with a standard iodine solution to show the distribution of starch.

Dry Weights.—For determination of dry weights plants were dried to constant weight in an oven run at 110° C.

Ash Determination.—Three grams of dry leaf material of the different plants were put into weighed crucibles and burned over a bunsen burner until a large part of the carbon had disappeared. To finish the burning, the crucibles were put into an electric oven at 600° C.

Experimental Observations

SERIES I

For all varieties of plants this series is divided into three parts, group H, which includes the plants rayed at 50 inches from the light; group F, those rayed at 100 inches; and as controls, group G, the same number of plants not rayed.

Series I H (rayed at 50 inches from the light without a screen).—Six young seedlings of *Cucumis* were rayed. The first evidence of the effect of ultra-violet rays appeared on the eighth day, when a slightly shiny appearance of the upper epidermis was noted. By the twelfth day there was evident curling of the edges of the leaf. At the end of three weeks the rolling of the leaves was very evident and the lower ones were turning brown and dying. The young leaves never attained as large a size as those on the control plants. By the end of the twenty-ninth day, when the plants received an exposure of fourteen minutes, one to three flowers were present, but the younger leaves were so rolled that the upper surface was hardly visible. When samples of the leaves were taken at the end of four weeks for anatomical study, they were found to be very brittle. The plant as a whole was very stiff and erect.

The control plants (G) had slightly more leaves and were a little taller. They also had several more flowers. Not only were the leaves greater in number but greater in size, being twice that of the rayed leaves. No rolling of the leaves was noted in the control plants. The color of the leaves was the same in both rayed and control plants except in the older rayed leaves which were brownish.

Six *Ipomoea* plants were used. By the sixth day the younger leaves showed a slightly blistered appearance which increased as time went on. By the eleventh day the veins were brown and the larger leaves showed several brown spots which seemed to be more or less superficial. By the end of three weeks the edges of the leaves had turned down. Very few leaves were shed. At the end of four weeks these leaves were also found to be brittle. The control plants again showed larger and more numerous leaves with no browning.

In the six *Nicotiana* plants, the first effect of raying was noticed on the eleventh day, when the margin of the leaves appeared wavy. By the thirteenth day the edges were definitely rolling upward. About the same time the upper surface became very shiny, and the leaves were so brittle it was almost impossible not to crack them. At the end of three weeks the older leaves were turning yellow and the younger leaves were so rolled that the upper surface was hardly visible, though no leaves were shed. The control plants showed none of these characteristics, the upper surface of the leaves being very hairy and the leaves larger.

The four varieties of *Coleus Blumei* were put into two groups according to their resistance to ultra-violet radiation. The group most sensitive to ultra-violet contained vars. *Verschaffeltii* and "Spotted Gem." At the end of five days a fading of the red color was noticed, and at the end of ten days practically all the red color had disappeared. The glossy upper surface was broken only by the bases of the hairs appearing as dots. The two halves of the leaves were rolled upward toward the midrib and the tips downward, so that the leaves appeared to be only half their normal size and were very brittle (pl. 22, fig. 4). By the end of four weeks all the older leaves had fallen and only a few of the

younger remained and those were very small and abnormal in shape.

The other group containing vars. "Trailing Queen" and "Defiance" seemed to be a little more resistant to ultra-violet rays. Here the first indication of a loss of red color appeared the eighth day. About the same time the shiny dotted appearance of the upper surface of the leaves was observed. The same rolling of the leaves was noted as in the other group. "Trailing Queen" lost very few leaves even at the end of four weeks but var. "Defiance" began to shed its leaves at the end of three weeks.

In the varieties of *Coleus* where any red color was present in the stem a loss of it began to be noted in the tip of the stem at the end of five days and a complete loss at the end of ten days. If after a raying of four weeks these plants were put back under normal greenhouse conditions the red color appeared again to a certain extent in the decolorized tip of the stem and the new growth of stem and leaves was normal.

Ten very young seedlings of *Raphanus* were rayed. At the end of eight days the typical curling upward and shiny appearance of the leaves was noted. Here the rayed leaves seemed to be a little deeper green than the control leaves. At the end of four weeks the leaves and petioles were almost as brittle as the rayed *Nicotiana* leaves. At the end of eight weeks the plants were so curled they appeared almost dead. The roots of the control plants, as well as the leaves, were much larger, as will be seen in pl. 21, fig. 7.

Two sets of *Lactuca*, containing ten plants each, were used, one set having two leaves and the other nine to ten. The object was to see if the older plants would be more resistant to ultra-violet radiation. The set of plants having two leaves never seemed to get much larger, as will be seen in pl. 22, figs. 2 and 3. At the end of two weeks the leaves were noticeably smaller and fewer than on control plants. All the new ones formed were abnormal and the older ones soon dried up and dropped off. As time went on the difference between the rayed and control plants became the most striking of any of the plants tried. At the end of eight weeks the rayed plants had an average of 4.25 leaves per plant while their controls had 13.

This and one set of *Raphanus* plants were the only groups of plants under Series I H that were rayed for eight weeks, the others being discontinued at the end of four weeks. A comparison of these plants at the end of four weeks and eight weeks with similar plants rayed at 100 inches (F) will be seen in pl. 22, figs. 2 and 3.

The set of plants having nine to ten leaves was found to be a little more resistant. At the end of one week the oldest leaves began to show tiny brown spots scattered over their surfaces. Soon after they began to dry up. At the end of three weeks all the older leaves were dead and the new ones smaller but not nearly as small as the new ones in the group having two leaves at the beginning. The leaves were very brittle and even the youngest very curly and brownish (pl. 22, fig. 1). At the end of eight weeks the rayed plants had an average of 18.32 leaves per plant and the controls 25.8 leaves (table 1).

TABLE I

SHOWING RATE OF GROWTH IN LACTUCA. FIGURES INDICATE THE AVERAGE NUMBER OF LEAVES PER PLANT

Date	Series number							
	I H		I G		I H		I G	
	Pres.	Lost	Pres.	Lost	Pres.	Lost	Pres.	Lost
Mar. 1	2.00	0	2.00	0	10.00	0	10.00	0
Mar. 8	3.60	0	3.40	0	10.60	2.00	11.60	1.30
Mar. 15	4.60	.60	4.60	0	10.40	4.50	12.20	2.60
Mar. 22	4.00	2.30	6.20	0	10.20	4.40	11.30	4.10
Mar. 29	4.30	3.10	7.00	1.50	12.60	2.10	14.30	1.33
Apr. 5	5.10	.30	8.00	.90	15.10	2.40	18.16	1.00
Apr. 12	5.00	1.10	10.00	1.20	15.66	5.33	21.20	3.90
Apr. 19	4.80	1.20	10.20	2.40	18.33	4.00	25.80	3.90
Apr. 26	4.25	5.00	13.00	1.00				
Net total	2.25	13.60	11.00	7.00	8.33	24.73	15.80	18.13

In *Bryophyllum* the first evidence of raying appeared the sixth day in the form of a glossy upper surface. At the end of two weeks the new leaves were very abnormal in form, the halves rolling upward from the midrib but the leaf itself not curling.

Three sets of *Phaseolus* seedlings were used with six plants in each. One set had both cotyledons intact, another had one

cotyledon removed, and the third had both cotyledons removed. The object was to determine if the removal of stored food had any influence on the effect of raying. In all cases growth was retarded and burning resulted. The leaves became very blistered and abnormal in shape. The difference between rayed and control plants with both cotyledons removed was very great but the difference with one cotyledon removed was about the same as where both cotyledons were intact (table v).

Series I F (rayed at 100 inches from the light without a screen).—The results with *Cucumis* here were in general the same, though never as marked for the same amount of raying, as in Series I H. The appearance of injury was retarded several days, being noted first on the fifteenth day when the plants received an exposure of 7½ minutes. For comparison of the size of rayed and control plants see table II and pl. 21, figs. 1 and 2. At the end of four weeks the average dry weight of rayed plants was 0.616 grams and the control plants 1.29 grams. At the end of eight weeks the leaves were as rolled as in Series I H.

TABLE II

SHOWING RATE OF GROWTH IN CUCUMIS. FIGURES EXPRESS AVERAGES PER PLANT

Date	Series number					
	I F			I G		
	Leaves pres.	Leaves lost	Ht. in cm.	Leaves pres.	Leaves lost	Ht. in cm.
Feb. 1	2.00	0	0	2.00	0	0
Feb. 8	6.00	0	7.35	5.25	0	6.00
Feb. 15	7.00	.75	9.55	7.00	1.25	7.70
Feb. 22	7.50	.20	11.60	8.00	.20	11.25
Feb. 29	9.00	.30	13.80	10.00	.28	14.00
Net total	7.00	1.25	13.80	8.00	1.73	14.00

The experiment using *Ipomoea* plants was continued for eight weeks. A slight browning of the veins was noticed at the end of the eighteenth day when the plants received an exposure of nine minutes. At the end of four weeks the usual blistering appeared as can be seen in pl. 21, fig. 6. About as many leaves were added as to the control plants but they never attained as large a size.

Nicotiana behaved very much the same here as in Series I H except that the effects were a little later in appearing.

The same four varieties of *Coleus Blumei* were used as in the preceding series and were again divided into two groups. The effect on both groups was somewhat less marked and much retarded, particularly as far as shedding leaves was concerned. The more resistant group shed no leaves until the fifth week, and at the end of seven weeks only a few had been shed (pl. 23, figs. 1–4). When these plants were put under normal greenhouse conditions at the end of eight weeks raying, they began to show normal growth and color after ten days, but at the end of four weeks they were still far behind the control plants (pl. 22, fig. 5).

Two sets of *Raphanus* were used, one with two leaves and the other with four to five leaves. Here there seemed to be very little difference in the effect produced whether the plant was just above ground or had several leaves. The effect of raying did not appear until the eighteenth day, but at the end of four weeks it was quite marked (pl. 21, fig. 5). At the end of eight weeks there was a noticeable difference in the number of leaves, the rayed plants averaging 6.2 and the control 8.42 leaves per plant (table III (a), and pl. 21, fig. 4).

The same two sets of *Lactuca* plants were again used. The same general results were found for the set having two leaves, but in the set having nine leaves the rayed plants produced as well as lost more leaves than the controls though they were never as large. A comparison of the effects produced here with those in Series I H can be well seen in pl. 22, figs. 1, 2, and 3 and table III (b). In addition to the above two sets of plants two more sets were used, one set consisting of two-leaved lettuce plants of a red variety and the other of old lettuce plants with fifteen leaves. Red lettuce was rayed to see if the color would disappear as it had done in *Coleus*. However, after raying for eight weeks the red color was still evident though partly masked by the brownish effect of raying. The old *Lactuca* plants were used in order to determine the effect of ultra-violet light on bud and flower formation. The same retarding effect was found though less with these older plants. At the end of eight weeks both rayed and control plants were

budded. The flower stalks of the control plants were greater in diameter and seemed to branch more at the top (pl. 26, fig.1).

Bryophyllum rayed under these conditions showed no curling of the leaves, due no doubt to their thickness. However, the leaves again rolled upward from the midrib. At the end of two weeks they had shiny brownish surfaces similar to those found in many of the other plants, and often parts of the new leaves formed were undeveloped. For a comparison of the rate of growth in rayed and control plants see table III (c) and pl. 26, fig. 5.

The ten *Zea Mays* seedlings were found to be as resistant to ultra-violet light as any of the plants used, showing the first evidence of any harmful effect the twenty-fourth day when they received a twelve-minute exposure. Even then the effect was slight, taking the form of a slight rolling upward of the edges of the leaves. When the rate of growth was compared, the rayed

TABLE III

SHOWING RATE OF GROWTH IN SERIES I F AND G. FIGURES INDICATE THE AVERAGES PER PLANT

Date	(a) Raphanus				(b) Lactuca							
	I F		I G		I F		I G		I F		I G	
	Pres.	Lost	Pres.	Lost	Pres.	Lost	Pres.	Lost	Pres.	Lost	Pres.	Lost
Mar. 1	2.00	0	2.00	0	2.00	0	2.00	0	9.0	0	9.0	0
Mar. 8	4.00	0	3.91	0	3.75	0	3.7	0	12.0	1.50	10.4	2.2
Mar. 15	5.63	0	5.63	0	4.28	0	4.2	0	12.9	2.70	10.6	2.1
Mar. 22	6.90	0.09	6.16	0.03	5.21	1.7	7.0	0	12.9	3.65	10.75	2.3
Mar. 29	6.90	1.00	6.53	0.03	6.07	3.2	7.4	1.7	10.35	5.80	9.6	4.2
Apr. 5	6.60	1.60	6.64	1.06	6.85	1.4	9.2	0.7	12.6	1.80	12.4	1.5
Apr. 12	7.20	1.00	7.71	0.10	8.80	1.7	11.8	0.4	15.5	2.50	15.5	.7
Apr. 19	6.20	1.60	8.42	0.18	8.77	3.3	12.6	2.2	19.0	3.66	18.4	3.5
Apr. 25					11.55	1.6	16.4	1.8	22.1	1.40	20.6	1.5
Net total	4.20	5.29	6.42	1.40	9.55	12.9	14.4	6.8	13.1	23.01	11.6	16.02

Date	(c) Bryophyllum				(d) Zea Mays			
	I F		I G		I F		I G	
	Lvs. pres.	Ht. in cm.	Lvs. pres.	Ht. in cm.	Lvs. pres.	Ht. in cm.	Lvs. pres.	Ht. in cm.
Jan. 24	12.59	13.14	13.71	14.35	....	....	....	....
Feb. 1	13.71	13.85	14.28	15.71	3.25	3.31	3.50	3.62
Feb. 8	14.85	15.14	15.71	17.35	3.75	5.2	4.00	5.37
Feb. 15	15.14	16.21	16.85	18.57	4.50	6.37	5.00	8.00
Feb. 22	17.00	17.04	17.42	19.07	5.00	8.43	6.25	9.94
Feb. 29					6.00	10.60	6.90	14.20
Net total	4.41	3.90	3.71	4.72	6.00	10.60	6.90	14.20

plants showed a noticeable retardation (table III (d) and pl. 26, fig. 4).

SERIES II

Plants in this series were under exactly the same conditions as those in Series I except that here a screen of vita glass was used. The series was again divided into three parts, group A, rayed at 50 inches from the light, group B, rayed at 100 inches, and group E, which was the control for both this series and Series III. All plants rayed were treated daily for seven weeks.

Series II A (rayed at 50 inches from the light with a screen of vita glass).—Plants rayed under these conditions responded very differently.

In ten young *Cucumis* seedlings exposed to ultra-violet leaves were produced a little more rapidly than in the control plants (E) but at the end of seven weeks the control plants had slightly more leaves than the rayed ones. The size and color seemed to be about the same for both. The stems elongated almost equally for the first three weeks and then increased very rapidly in the rayed plants, so that at the end of seven weeks they averaged eight to nine centimeters longer and were noticeably greater in diameter than the control plants (table IV (a) and pl. 24, fig. 1). Flowers appeared on the rayed plants two days earlier than on the control plants. At the end of seven weeks the rayed plants averaged 2.3 flowers and the control plants only 1.2 flowers per plant.

Ten cuttings of *Ipomoea* of as near the same size as possible were rayed. Even at the end of seven weeks there was very little difference in height between them and the controls, though the average number of leaves added was much greater in the rayed plants (table IV (b) and pl. 24, fig. 2). The leaves of both rayed and control plants were of about the same size and color.

Observations on fifteen *Nicotiana* plants point toward a retardation of growth, though there was no evidence of any burning. The leaves were about the same in number, size, and color. The stem, however, was taller and smaller in diameter in the control plants. No difference was noticed in the time of

flowering. In general, the rayed plants gave the appearance of being more stocky (table IV (c)).

Ten young *Zea Mays* seedlings were used. At first the control plants grew taller, measuring from the base to the highest node. During the last few days, however, the rayed plants grew very rapidly and surpassed the controls. The rayed stalks were also larger in diameter. The leaves on the rayed plants not only outnumbered those on the control plants, but were from 1.5 to 2.0 cm. wider in the middle, those on the controls averaging 4.0 cm. in width (table IV (d) and pl. 24, fig. 3).

From the very beginning the twenty rayed plants of *Lactuca* produced slightly more leaves than the controls. The leaves of both were the same in color, texture, and size (table IV (e) and pl. 24, fig. 4).

The size of the leaves on the ten rayed *Raphanus* seedlings equalled those on the controls, but there were slightly more leaves on the latter (table IV (f) and pl. 25, fig. 1).

Coleus Blumei vars. "Spotted Gem" and *Verschaffeltii* have been found to be the varieties most sensitive to ultra-violet light, and six cuttings of each as near the same size as possible were used. Both varieties showed the same characteristics. From the very beginning the rayed plants showed greater growth both as to number and size of leaves, and as to height and diameter of stem (table IV (h and i), and pl. 25, figs. 2 and 3). The red color did not seem to be affected as it was in Series I.

Eight cuttings of *Bryophyllum* were rayed. At first the controls grew taller, with a greater number of leaves, but during the last few weeks the rayed plants much surpassed the controls (table IV (g) and pl. 25, fig. 4).

Three sets of *Phaseolus* seedlings of six each were used as in Series I. Those with both cotyledons intact and with one cotyledon removed were taller and had more leaves than the corresponding control plants. Those with both cotyledons removed had slightly more leaves than the corresponding control plants, but were shorter (table v).

Series II B (rayed at 100 inches from the light using a screen of vita glass).—The same number of *Cucumis* plants was used as in Series I A. From the very first the number of leaves on the

rayed plants exceeded those on the controls, but the size of the leaves was about the same in both. The rayed leaves in this group seemed a little deeper green than did the controls. All through the experiment the stems of the rayed plants increased in both length and thickness more rapidly than those of the control plants, and at the end of seven weeks were a little greater in length than the stems of the plants in Series II A (table IV (a) and pl. 24, fig. 1).

About the same number of leaves was present on the ten *Ipomoea* cuttings in this series as in Series II A, which was much greater than in control plants. The stem, however, was greater in length here than in either Series II A or the control E (table IV (b) and pl. 24, fig. 2).

In the fifteen *Nicotiana* plants rayed little difference was found from Series II A either in number or color of leaves or in length and thickness of stem. The control plants had about the same number of leaves but were taller (table IV (c)).

In this group the ten *Zea Mays* seedlings showed a slight increase in number of leaves over those in Series II A and a greater increase over the control plants in E. In average growth in height and diameter of the stalk this group exceeded both the control plants in E and the rayed plants in A (table IV (d) and pl. 24, fig. 3).

Here, as in Series II A, twenty *Lactuca* plants were rayed. All through the experiment there was a slight increase in number of leaves over that in the control plants though the size of the leaves was a little greater in the control plants (table IV (e), and pl. 24, fig. 4).

The ten rayed *Raphanus* seedlings showed leaves equalling those of the control plants in size but fewer in number. The seedlings in this group were almost identical with those in Series II A (table IV (f), and pl. 25, fig. 1).

The same number of *Coleus* cuttings was used as in Series II A. As to number of leaves produced the plants in this group about equalled those in Series II A, but much surpassed the controls in E. Here the plants exceeded in height both those in Series II A and the controls E (table IV (h and i) and pl. 25, figs. 2 and 3).

The *Bryophyllum* cuttings in this group produced about the

same number of leaves as the controls but increased a little more in height than did the controls. Plants in Series II A surpassed this group both in number of leaves and in height (table IV (g) and pl. 25, fig. 4).

SERIES III

The same conditions were present in this series except that instead of vita glass a screen of quartz-lite glass was used. This series also was divided into three parts, group C, rayed at 50 inches from the light, group D, rayed at 100 inches, and group E, again the control. The same number of plants were used in each case as in Series II.

Series III C (plants rayed at 50 inches from the light using a screen of quartz-lite glass).—The number of leaves produced on rayed *Cucumis* seedlings was a little more than in Series II A, but a little less than in Series II B. As to growth in height both Series II A and B surpassed this group by about three centimeters. However, this group surpassed the control by more than five centimeters (table IV (a) and pl. 24, fig. 1).

The *Ipomoea* cuttings in this group produced more leaves than in either A or B of Series II, though the growth in height was a little less here than in those groups. This group showed better growth than the control in all respects (table IV (b) and pl. 24, fig. 2).

There was little difference between the growth of the *Nicotiana* plants here and in groups A and B of Series II. The control plants surpassed all three mentioned groups in height, but about equalled the other groups in number of leaves (table IV (c)).

The *Zea Mays* seedlings here were almost identical with those in Series II B as to number and size of leaves and as to height of plant. It would be hard to determine from external observation which of these two groups produced the better growth (table IV (d) and pl. 24, fig. 3).

The *Lactuca* plants in this group showed more leaves than either the control plants or the plants in Series II A and B. However, the leaves in this group of plants were a little smaller than in the control plants (table IV (e) and pl. 24, fig. 4).

The average number of leaves present in *Raphanus* seedlings in this group was slightly less than in the controls, but otherwise the plants were identical (table IV (f) and pl. 25, fig. 1).

Both varieties of *Coleus* again showed similar results. The cuttings in this group showed more growth in height and number of leaves than did the controls but not as much as in either A or B of Series II (table IV (h and i) and pl. 25, figs. 2 and 3).

The *Bryophyllum* cuttings in this group surpassed the control plants and those in Series II B both in number of leaves and in height. However, the growth in this group did not equal that in Series II A (table IV (g) and pl. 25, fig. 4).

As in Series II A, three sets of *Phaseolus* seedlings were used. Those with both cotyledons intact and with one cotyledon removed were a little taller and had slightly more leaves than the control plants, but were not quite as tall nor did they possess quite as many leaves as those in Series II A. The plants with both cotyledons removed showed less growth in height than the corresponding controls, but a little more than those in Series II A. The number of leaves present differed very little (table V).

Series III D (plants rayed 100 inches from the light using a screen of quartz-lite glass).—*Cucumis* seedlings in this group differed very little from those in group C and thus were several centimeters greater in length than the controls (table IV (a) and pl. 24, fig. 1).

Ipomoea plants showed greater growth in height in this series than in Series III C, with about the same number of leaves present in each series (table IV (b)).

The *Nicotiana* plants closely resembled those in Series II A and B, being stocky while the controls were much taller (table IV (c)).

Seedlings of *Zea Mays* in this group were not quite as tall as in the other groups mentioned, but nevertheless surpassed the control plants. As to number of leaves present this group about equalled the other groups. All the rayed groups in Series II and III, as previously mentioned, possessed leaves from one and a half to two centimeters wider in the middle than the control leaves (table IV (d) and pl. 24, fig. 3).

Lactuca plants in this group gave a slightly smaller count of leaves than in Series III C, but more than in Series II A and B and also more than the control plants. Little difference was noticed between the size of the leaves here and in the control plants (table IV (e), and pl. 24, fig. 4).

Raphanus plants showed slightly fewer leaves than in Series III C and thus fewer than the control plants (table IV (f) and pl. 25, fig. 1).

Both varieties of *Coleus* plants in this group surpassed the control both in number of leaves and growth in height, but showed fewer leaves and less growth in height than in Series II A and B and Series III C (table IV (h and i) and pl. 25, figs. 2 and 3).

Cuttings of *Bryophyllum* showed fewer leaves than in Series II A or Series III C and about the same number as the control plants and Series II B. However, this group showed almost as great growth in height as in Series III C, which surpassed Series II A and B and also the controls (table IV (g)).

TABLE IV

SHOWING THE RATE OF GROWTH OF PLANTS IN SERIES II AND III. FIGURES REPRESENT AVERAGE NUMBER OF LEAVES PER PLANT; AND HEIGHT IN CENTIMETERS

(a) Cucumis

Date	Series II				Series III				Control	
	A		B		C		D		E	
	Lvs.	Ht.	Lvs.	Ht.	Lvs.	Ht.	Lvs.	Ht.	Lvs.	Ht.
Oct. 24	2.00		2.00		2.00		2.00		2.00	
Oct. 31	3.50	7.45	3.80	7.60	3.80	6.35	3.60	7.75	3.00	6.8
Nov. 7	5.00	8.90	5.00	10.00	4.90	8.30	5.00	9.85	4.80	7.9
Nov. 14	5.60	9.85	6.00	11.20	5.87	9.50	6.00	10.60	5.77	9.5
Nov. 21	7.10	13.00	6.70	14.00	6.77	11.33	6.80	13.05	5.90	11.1
Nov. 28	7.20	16.90	7.00	19.20	6.77	14.83	6.80	17.15	6.77	13.0
Dec. 5	7.10	22.70	8.11	24.72	7.66	20.00	6.80	22.25	7.44	17.6
Dec. 12	7.30	29.05	8.22	29.77	7.77	26.04	7.10	27.90	7.65	20.5
Net total	5.30	29.05	6.22	29.77	5.77	26.04	5.10	27.90	5.65	20.5

(b) Ipomoea

Date	Series II				Series III				Control	
	A		B		C		D		E	
	Lvs.	Ht.	Lvs.	Ht.	Lvs.	Ht.	Lvs.	Ht.	Lvs.	Ht.
Oct. 24	11.12	11.25	7.25	12.82	9.12	8.44	8.25	8.56	5.87	5.75
Oct. 31	14.62	11.50	9.78	13.81	11.87	9.64	10.37	11.37	6.75	6.25
Nov. 7	16.75	12.62	11.75	14.81	13.62	10.59	13.00	12.25	8.50	6.94
Nov. 14	18.25	13.63	14.75	15.21	16.00	11.37	16.25	12.81	10.31	7.97
Nov. 21	20.70	14.50	18.00	16.57	19.87	12.75	17.62	14.06	10.75	8.43
Nov. 28	24.00	15.18	22.00	17.42	24.56	15.21	22.00	15.31	12.75	9.81
Dec. 5	26.75	15.68	25.71	19.57	27.42	16.50	26.06	15.42	14.42	10.35
Dec. 12	28.80	16.50	27.33	20.66	30.14	17.85	31.51	18.00	14.50	10.50
Net total	17.68	5.25	20.08	7.84	21.02	9.41	23.26	9.44	8.63	4.75

(c) Nicotiana

Date	Series II				Series III				Control	
	A		B		C		D		E	
	Lvs.	Ht.	Lvs.	Ht.	Lvs.	Ht.	Lvs.	Ht.	Lvs.	Ht.
Oct. 24	4.46		4.10		4.10		4.46		4.46	
Oct. 31	6.40		6.40		6.40		6.60		6.13	
Nov. 7	7.93		7.53		8.06		8.28		7.53	
Nov. 14	9.80		10.07		9.80		9.07		9.21	
Nov. 21	9.50	5.00	9.71	4.89	10.26	5.03	9.70	4.69	9.57	5.85
Nov. 28	10.41	6.12	9.80	6.66	10.58	7.05	9.80	6.65	10.25	8.08
Dec. 5	12.20	9.25	11.90	9.45	12.20	8.95	11.40	9.05	12.55	15.00
Dec. 12	13.20	13.05	13.45	13.45	12.70	13.25	13.20	13.30	12.88	19.05
Net total	8.74	13.05	9.35	13.45	8.60	13.25	8.74	13.30	8.42	19.05

(d) Zea Mays

Date	Series II				Series III				Control	
	A		B		C		D		E	
	Lvs.	Ht.	Lvs.	Ht.	Lvs.	Ht.	Lvs.	Ht.	Lvs.	Ht.
Oct. 24	Just above ground									
Oct. 31	3.50	4.62	3.62	5.18	3.38	5.19	3.50	4.62	2.88	4.77
Nov. 7	4.38	7.31	4.88	7.79	4.50	7.87	4.62	7.56	3.80	7.55
Nov. 14	5.12	7.93	5.62	9.43	5.37	9.31	5.25	8.37	5.20	8.60
Nov. 21	5.75	9.43	6.75	12.00	5.66	10.94	6.25	10.68	5.60	10.20
Nov. 28	6.75	12.93	7.85	16.35	7.11	14.61	7.37	14.31	6.40	14.10
Dec. 5	8.00	15.56	8.14	18.57	8.00	17.22	8.33	16.81	7.00	15.80
Dec. 12	9.00	18.75	9.71	20.00	9.22	20.00	9.28	18.42	8.00	17.37

	(e) Lactuca					(f) Raphanus				
Date	Series II		Series III		Control	Series II		Series III		Control
	A	B	C	D	E	A	B	C	D	E
	Lvs.	Lvs.	Lvs.	Lvs.	Lvs.	Lvs.	Lvs.	Lvs.	Lvs.	Lvs.
Oct. 24	8.25	8.10	8.20	8.00	8.10	2.00	2.00	2.00	2.00	2.00
Oct. 31	13.35	12.35	13.15	13.15	12.65	2.80	2.90	2.30	3.30	2.90
Nov. 7	16.90	16.45	16.95	16.45	15.70	4.20	4.40	4.40	4.80	4.20
Nov. 14	20.80	20.45	21.65	20.35	20.25	5.70	6.00	5.40	5.70	5.80
Nov. 21	22.60	23.25	25.20	21.60	20.35	5.80	5.60	5.90	4.70	5.60
Nov. 28	25.61	25.27	25.05	24.52	23.11	5.80	5.60	4.90	5.10	5.37
Dec. 5	27.07	27.78	26.68	29.06	25.85	6.55	6.60	6.10	6.10	7.00
Dec. 12	28.38	27.57	32.18	30.52	26.90	7.22	7.10	6.60	6.40	7.60
Net total	20.13	19.47	23.98	22.52	18.80	5.22	5.10	4.60	4.40	5.60

(g) Bryophyllum

Date	Series II				Series III				Control	
	A		B		C		D		E	
	Lvs.	Ht.	Lvs.	Ht.	Lvs.	Ht.	Lvs.	Ht.	Lvs.	Ht.
Oct. 31	9.37	7.46	8.66	5.47	9.33	6.61	8.50	5.34	6.75	5.25
Nov. 7	10.37	7.62	11.00	5.81	10.11	7.05	10.00	5.87	8.00	7.18
Nov. 14	11.37	8.81	11.25	6.75	11.11	8.16	10.75	6.63	9.25	7.75
Nov. 21	12.12	9.87	11.25	7.43	11.90	9.27	11.50	8.00	10.25	7.94
Nov. 28	14.37	10.75	12.12	9.25	13.10	11.44	12.50	10.12	10.75	8.25
Dec. 5	16.28	13.85	13.5	10.68	15.22	11.50	12.75	11.25	11.25	9.25
Dec. 12	18.37	14.94	14.12	12.18	18.00	13.61	14.00	13.37	12.25	10.00
Net total	9.00	7.48	5.46	6.71	8.67	7.00	5.50	8.30	5.50	3.75

(h) Coleus Blumei var. Verschaffeltii

Date	Series II				Series III				Control	
	A		B		C		D		E	
	Lvs.	Ht.	Lvs.	Ht.	Lvs.	Ht.	Lvs.	Ht.	Lvs.	Ht.
Oct. 24	7.66	3.75	9.16	4.08	8.83	3.83	9.50	4.00	6.83	3.25
Oct. 31	10.00	4.58	12.00	5.58	10.50	4.83	11.33	5.08	8.33	3.66
Nov. 7	13.66	5.66	17.66	7.83	14.00	6.25	17.16	6.25	11.00	4.66
Nov. 14	18.16	6.46	25.66	9.16	22.50	7.41	26.33	7.75	14.00	5.38
Nov. 21	24.50	8.33	34.00	11.25	32.40	9.40	29.33	9.50	15.50	6.16
Nov. 28	33.66	9.50	43.66	14.91	41.80	10.70	37.66	10.50	19.83	7.58
Dec. 5	40.66	10.66	51.16	16.75	53.60	12.10	43.83	12.66	25.83	10.08
Dec. 12	67.00	14.40	69.30	18.25	64.60	14.30	58.50	14.26	35.16	10.75
Net total	59.34	10.65	60.14	14.17	55.77	10.47	49.00	10.26	28.33	7.00

(i) Coleus Blumei var. "Spotted Gem"

Date	Series II				Series III				Control	
	A		B		C		D		E	
	Lvs.	Ht.	Lvs.	Ht.	Lvs.	Ht.	Lvs.	Ht.	Lvs.	Ht.
Oct. 24	10.10	3.33	9.66	3.50	7.00	1.66	6.00	2.00	6.00	2.00
Oct. 31	12.33	6.33	12.00	4.83	7.60	2.08	9.33	2.25	8.66	2.16
Nov. 7	19.60	6.50	20.30	6.50	9.33	2.75	11.00	3.06	10.66	3.00
Nov. 14	24.00	7.58	28.33	7.92	14.00	3.33	16.66	3.33	12.66	3.16
Nov. 21	34.00	9.33	41.00	9.83	20.00	4.50	19.00	4.75	12.66	3.83
Nov. 28	48.30	11.16	51.30	13.33	26.60	5.16	20.00	6.16	15.30	4.83
Dec. 5	58.33	13.16	64.00	16.16	32.00	5.66	22.66	6.83	18.00	6.33
Dec. 12	78.30	15.66	84.00	18.00	36.60	7.16	37.60	8.10	25.66	7.10
Net total	68.20	12.33	74.34	14.50	29.60	5.50	31.60	6.10	19.66	5.10

TABLE V

(a) SHOWING RATE OF GROWTH IN PHASEOLUS SEEDLINGS WITH BOTH COTYLEDONS PRESENT. FIGURES REPRESENT AVERAGE NUMBER OF LEAVES PER PLANT AND HEIGHT IN CENTIMETERS

Date	Series I H		Series II A		Series III C		Control E	
	Lvs.	Ht.	Lvs.	Ht.	Lvs.	Ht.	Lvs.	Ht.
Oct. 28	2.00	5.25	2.00	4.37	2.00	4.66	2.00	4.21
Nov. 5	3.75	10.37	3.33	10.60	3.50	12.00	3.15	10.75
Nov. 12	5.00	12.75	4.33	13.60	5.00	13.83	4.50	13.37
Nov. 19	5.50	15.00	5.00	17.20	5.10	17.91	4.80	15.71
Nov. 26	5.50	15.80	6.00	22.80	5.30	22.91	5.00	21.08
Net total	3.50	9.55	4.00	18.43	3.30	18.25	3.00	16.87
Av. no. flowers	0		1.6		3.33		1.5	

(b) SHOWING RATE OF GROWTH IN PHASEOLUS SEEDLINGS WITH ONE COTYLEDON REMOVED

Date	Series I H		Series II A		Series III C		Control E	
	Lvs.	Ht.	Lvs.	Ht.	Lvs.	Ht.	Lvs.	Ht.
Oct. 28	2.00	5.62	2.00	4.16	2.00	4.66	2.00	3.50
Nov. 5	3.25	10.37	3.00	10.40	3.10	9.16	3.30	9.20
Nov. 12	4.00	12.37	4.20	13.00	5.10	12.70	4.00	11.20
Nov. 19	5.00	14.56	4.90	16.40	5.20	13.30	4.50	13.50
Nov. 26	5.00	15.00	5.60	20.70	5.20	20.58	5.00	14.75
Net total	3.00	9.38	3.60	16.54	3.20	15.92	3.00	11.25
Av. no. flowers	0		2.4		.8		1.4	

(c) SHOWING RATE OF GROWTH IN PHASEOLUS SEEDLINGS WITH BOTH COTYLEDONS REMOVED

Date	Series I H		Series II A		Series III C		Control E	
	Lvs.	Ht.	Lvs.	Ht.	Lvs.	Ht.	Lvs.	Ht.
Oct. 28	2.00	5.25	2.00	3.33	2.00	5.33	2.00	4.50
Nov. 5	2.25	8.00	2.50	7.25	2.70	7.46	2.50	8.90
Nov. 12	3.30	9.87	3.60	9.08	4.80	11.00	4.20	12.62
Nov. 19	4.30	11.50	4.20	11.41	4.80	13.40	4.50	14.36
Nov. 26	4.30	11.75	5.10	15.00	4.80	18.50	4.70	18.20
Net total	2.30	6.50	3.10	11.67	2.80	13.17	2.70	13.70
Av. no. flowers	0		.5		.8		1.0	

According to Beeskow ('28) and Delf and Ritson (Delf, Ritson, and Westbrook '27) a daily exposure to ultra-violet of as long as thirty seconds produces no harmful effects in Soy beans and *Trifolium* and might cause a slight increase in growth. Thus several experiments were undertaken to see if this might not be true of other plants. Fifteen young *Nicotiana* plants were rayed at 100

inches from the light without a screen for thirty seconds each day for a period of four weeks. At the end of that time the rayed plants showed a noticeable increase in growth over the control plants (table VI). The same experiment was tried with three varieties of *Coleus* with the same results. Here the increase was not only in number of leaves, but also in height (table VI and pl. 26, fig. 2). Very young lettuce plants were also rayed with the same results.

Next, the exposure of one minute each day at 100 inches from the light was tried on the same three varieties of *Coleus*, with absolutely no change in color. There was, however, a slight retardation in the rate of growth at the end of two weeks, but even at the end of four weeks it was not very noticeable.

TABLE VI

SHOWING RATE OF GROWTH IN PLANTS RAYED 30 SECONDS EACH DAY AT 100 INCHES FROM THE LIGHT, USING NO SCREEN

Date	(a) Nicotiana		(b) Coleus Blumei var. Verschaffeltii			
	Rayed	Control	Rayed		Control	
	Lvs. pres.	Lvs. pres.	Lvs. pres.	Ht. in cm.	Lvs. pres.	Ht. in cm.
Jan. 24	4.26	3.93	12.25	7.50	10.60	7.83
Feb. 1	5.60	5.26	15.50	8.62	11.30	8.00
Feb. 8	7.10	7.13	23.00	10.00	16.60	9.30
Feb. 15	8.46	7.66	28.75	12.12	21.00	10.00
Feb. 22	9.93	8.66	35.45	12.75	29.00	11.30
Total	5.67	4.73	23.20	5.25	18.40	3.34

Date	(c) Coleus Blumei var. "Defiance"				(d) Coleus Blumei var. "Spotted Gem"			
	Rayed		Control		Rayed		Control	
	Lvs. pres.	Ht. in cm.	Lvs. pres.	Ht. in cm.	Lvs. pres.	Ht. in cm.	Lvs. pres.	Ht. in cm.
Jan. 24	11.00	8.37	7.00	4.00	13.50	8.62	15.75	8.87
Feb. 1	14.50	9.50	7.50	4.52	16.25	9.37	18.25	9.25
Feb. 8	19.25	11.87	8.75	6.25	32.75	10.62	33.50	9.75
Feb. 15	24.75	15.00	9.25	8.50	47.00	12.37	44.75	11.25
Feb. 22	26.50	16.50	13.75	10.37	49.75	12.75	50.50	12.00
Total	15.50	8.13	6.75	6.37	36.25	4.13	34.75	3.13

ANATOMICAL

(ALL MEASUREMENTS WERE MADE WITH AN EYEPIECE MICROMETER)

Leaves.—A cross-section of a *Cucumis* leaf rayed under the conditions present in Series I F was measured and found to be a little thinner than a corresponding section from a non-rayed leaf. When the structure of the two sections was compared, it was observed that the rayed section was lacking in upper epidermis, with only the collapsed walls remaining as a false cuticle, which no doubt gave the glossy surface to the leaf. Also the protoplasm in most of the palisade cells had drawn away slightly from the ends of the cells nearest the epidermis. The chloroplastids in the rayed section were found to be more numerous in the ends of the palisade cells nearest the spongy tissue. Another difference was the presence of fewer air-spaces in the rayed section (pl. 28, figs. 4 and 5 and table VII (b)). This corresponds well with the results found by Bailey ('94), Kluyver ('11), and Westbrook (Delf, Ritson, and Westbrook, '27).

When a cross-section of a *Cucumis* leaf, rayed as in Series II A, was measured it was found to be a little thicker than a similar section from a non-rayed plant. A leaf from Series II B was found to be still thicker. It will be remembered that this was also the group where greatest growth in height was found. A leaf from Series III C was thicker than Series II A but thinner than Series II B. A leaf from Series III D was slightly thicker than the control though not as thick as a leaf from Series II A. The control leaf showed very long palisade cells with many air-spaces between them and also among the cells of the spongy tissue. In Series II B where the thickest leaf was found, there were larger air-spaces than in the control leaf. The palisade cells in all rayed leaves in Series II and III were a little shorter than in the control leaves. The thinnest rayed leaf (Series III D) showed fewer air-spaces than the control and instead smaller and more numerous cells. The number and position of the plastids was about the same in all leaves (pl. 29, figs. 1–3, and table VII (k)).

The cross-section of a rayed leaf of *Ipomoea* from Series I H was found to be much thinner than an unrayed leaf. Here, as in *Cucumis*, the epidermis had collapsed, forming a heavy cuticle.

Occasionally, however, an epidermal cell remained intact. The protoplasm of a few of the palisade cells had drawn away from the end nearer the epidermis, and the cells themselves were shorter. A section from an *Ipomoea* leaf in Series I F proved to be of the same thickness as the one from Series I H. Here, however, the epidermis was not collapsed but thinner, each cell being absolutely distinct. The palisade cells were longer than in Series I H but not as long as the controls. There were fewer air-spaces here than in either the control leaf or the leaf in Series I H. This is probably due to the fact that Series I F was rayed for a period of eight weeks and Series I H for only four weeks (table VII (d)).

When rayed *Ipomoea* leaves from Series II A were examined, they were found to be thinner than control leaves. Leaves from Series II B were slightly thinner than those in II A. The palisade cells in both the above-mentioned groups were thinner than palisade cells in control leaves, as were also the upper epidermal cells.

Rayed leaves in Series III C about equalled the control leaves in thickness and length of palisade cells, though the upper epidermis here was still thinner than in the control leaves. Leaves from Series III D were by far the thickest in any of the series. Here the palisade cells and epidermal cells were also longer than in any of the other groups. Air-spaces were found to be much greater and more numerous than in sections of control leaves. Chloroplastids seemed to be more numerous here also (table VII (p), and pl. 29, figs. 4 and 5).

The cross-section of a rayed *Nicotiana* leaf from Series I H was again found thinner than an unrayed leaf. The same collapsing of the epidermis and shrinking of the protoplasm in the palisade cells were also found (pl. 27, fig. 7, and table VII (e)).

Rayed *Nicotiana* leaves from Series II A and B and III C were about the same thickness as those of non-rayed plants. The palisade cells from Series II A and B were a little longer than corresponding cells in a control leaf. A *Nicotiana* leaf from Series III D proved to be much thicker than one from any of the other groups mentioned. Also its palisade cells were longer, and it contained many more air-spaces. However, the upper epidermis

was thinner here than in a non-rayed leaf (pl. 27, figs. 5 and 6, and table VII (o)). It will be remembered that this group, while it did not show greatest growth in height, was the most stocky in appearance and produced flowers at the same time as did the control plants showing greatest growth in height.

When cross-sections of *Zea Mays* leaves were examined it was found that all rayed leaves in Series II and III were much thicker than non-rayed ones, the thickest being present in Series III C, which was rayed for seven weeks at 50 inches from the light using a screen of quartz-lite glass. These leaves also showed the thinnest epidermis and the best-developed vascular bundles. Leaves in Series II A and B were next in thickness, and both had well-developed bundles. Leaves in Series III D were the nearest like those of the control plants, having very thick epidermis and less well-developed bundles. In general, there seemed to be a thicker cuticle present in rayed leaves than in control leaves (pl. 32, figs. 1–6, and table VII (n)).

Cross-sections of *Coleus* leaves in Series I H which were rayed at 50 inches without a screen showed the same collapsed epidermis and lack of air-spaces as were found in similarly treated leaves of other plants. However, here in addition there was a loss of red color. Not only did the color disappear from the epidermis when it collapsed, but also from the palisade cells, showing that the rays penetrate beyond the epidermis or else produce some substance which does. This corresponds well with the results found in animal tissue by Macht, Anderson and Bell ('28) (pl. 31, figs. 4 and 5).

Non-rayed *Coleus* leaves were found to be much thicker than those rayed. The thinnest leaves were found in Series II B, where there was also the greatest growth in height. According to increasing thickness the groups may be arranged as follows; Series II B, II A, III C, III D, and last, the control E. The palisade cells were shorter in Series II B than in any of the other groups, even including the control plants. There was absolutely no decrease in red color in any of the rayed plants in Series II and III. It appeared that in *Coleus* plants the growth in height was inversely proportional to both the thickness of the leaves and the number of air-spaces present (pl. 30, figs. 1–5, and table VII (l)).

Lactuca leaves rayed as in Series I H showed the characteristic collapse of at least part of the epidermis and the lack of air-spaces. In addition, there was no differentiation of palisade tissue. Leaves rayed as in Series I F for four weeks were similar to the controls except that they were a little thinner and developed palisade and epidermal cells that were a little shorter. The air-spaces were also fewer here than in control leaves. If their leaves were rayed for eight weeks instead of four, they were still thinner, had no well-defined palisade layer, and almost no air-spaces. In thickness they about equalled the leaves in Series I H.

When rayed *Lactuca* leaves from Series II and III were examined they were all found to be of about the same thickness and much thinner than corresponding control leaves. The palisade and epidermal cells were also shorter than those present in the control leaves.

Cross-sections of rayed *Raphanus* leaves in Series I F were only very slightly thinner than those of corresponding control leaves. There was the same collapse of epidermis, forming a false cuticle as in other leaves mentioned. The contents of the upper layer of palisade cells had disappeared, leaving them empty. Leaves in Series I H showed about the same injury as those in Series I F rayed for eight weeks. Rayed leaves in Series II and III were all thinner than similar control leaves, those in Series III D being the thinnest. The palisade and epidermal cells, however, seemed to be longer than in the control leaves. This would indicate fewer air-spaces in the rayed leaves in Series II and III than in corresponding non-rayed leaves.

Sections of *Bryophyllum* leaves rayed under the conditions of Series I H were also thinner than corresponding sections of non-rayed leaves. The characteristic lack of upper epidermis was observed and also a thicker under epidermis. Sections of leaves from this plant in Series II A were much thinner than those of control leaves, and there was no collapse of upper epidermis. Leaves from Series II B were about the same thickness as control leaves, but the epidermis was slightly thinner. Leaves in Series III C were thinner than in Series II B but thicker than in Series II A. Leaves from Series III D had longer upper epidermal

cells and were much thicker than any of the other leaves including the controls.

Cross-sections of *Phaseolus* leaves in Series I F were thinner than sections from control leaves. The epidermis was destroyed in some places, but in others the epidermal cells still remained intact. The contents of the palisade cells were much shrunken and the cells shorter. The chloroplastids were also collected in the end of the cells nearest the spongy tissue. Sections of *Phaseolus* leaves from Series II A were much thicker than control sections. They also had longer palisade and epidermal cells and more numerous air-spaces and chloroplastids. *Phaseolus* leaves from Series III C were also thicker than non-rayed leaves but not as thick as those in Series II A (pl. 28, figs. 1–3, 6, and table VII (c and m)).

TABLE VII

SHOWING THICKNESS OF LEAVES AND LENGTH OF CELLS IN MILLIMETERS FOR RAYED AND CONTROL PLANTS. CELL LENGTH TAKEN NORMAL TO LEAF SURFACE

	(a) Lactuca				(b) Cucumis		(c) Phaseolus		(d) Ipomoea		
	Con.	Series I			Con.	Series I	Con.	Series I	Con.	Series I	
	G	F	F′*	H	G	F	G	F	G	F′	H
Leaf	.1279	.101	.076	.074	.1247	.1226	.0938	.0814	.1565	.117	.117
Palisade	.0298	.021	.0156	.014	.045	.045	.0384	.0296	.0408	.034	.029
Upper epid.	.0138	.0137	.0109	.0107	.0135	(—)	.0119	(—) or .0114	.0243	.012	(—)
Lower epid.	.0107	.0091	.0107	or (—)† .009	.0068	.0126	.0098	.0102	.0239	.011	.0145

	(e) Nicotiana		(f) Bryophyllum		(g) Raphanus		(h) Raphanus				
	Con.	Series I	Con.	Series I	Con.	Series I	Series II		Series III		Con.
	G	H	G	H	G	F′	A	B	C	D	E
Leaf	.143	.1326	.460	.4338	.1604	.1612	.1582	.158	.149	.1293	.163
Palisade	.0525	.0529	(—)	(—)	.0495	.0635	.0495	.049	.047	.0411	.038
Upper epid.	.0218	(—)	.0153	(—)	.0142	(—)	.0148	.019	.015	.0134	.013
Lower epid.	.011	.0112	.0121	.0145	.0151	.0123	.01176	.0103	.009	.0117	.007

	(i) Lactuca					(j) Bryophyllum				
	Series II		Series III		Control	Series II		Series III		Control
	A	B	C	D	E	A	B	C	D	E
Leaf	.0884	.087	.0896	.0882	.1013	.360	.522	.4464	.8075	.5103
Palisade	.0182	.0207	.0204	.0176	.0263					
Upper epid.	.0128	.0154	.012	.0134	.0154	.0153	.0189	.0202	.0153	.0207
Lower epid.	.0078	.0109	.0092	.0089	.0126	.0121	.0099	.0126	.0144	.0121

* F′, plants rayed 8 weeks at 100 iches without a screen.
† (—), lacking.

	(k) Cucumis					(l) Coleus				
	Series II		Series III		Control	Series II		Series III		Control
	A	B	C	D	E	A	B	C	D	E
Leaf	.1307	.1397	.1363	.127	.1257	.1181	.1056	.1232	.1374	.138
Palisade	.0448	.0459	.0454	.0453	.0484	.0364	.0299	.037	.0371	.0375
Upper epid.	.0134	.0096	.0117	.0133	.0126	.021	.0184	.0159	.0156	.0168
Lower epid.	.007	.0117	.007	.0071	.0072	.0086	.0078	.0103	.007	.0112

	(m) Phaseolus					(n) Zea Mays				
	Series II		Series III		Control	Series II		Series III		Control
	A	B	C	D	E	A	B	C	D	E
Leaf	.1369		.1016		.0915	.1408	.1402	.1467	.1366	.1195
Palisade	.0518		.038		.036					
Upper epid.	.018		.0111		.010	.0263	.0260	.020	.0296	.0274
Lower epid.	.012		.0069		.0067	.0204	.0304	.026	.0196	.019

	(o) Nicotiana					(p) Ipomoea				
	Series II		Series III		Control	Series II		Series III		Control
	A	B	C	D	E	A	B	C	D	E
Leaf	.143	.143	.1444	.1584	.145	.1206	.1184	.1316	.168	.133
Palisade	.0525	.0498	.0362	.0487	.0414	.0355	.0375	.0467	.0604	.0476
Upper epid.	.0218	.019	.0148	.0162	.0207	.0179	.0193	.0188	.0243	.0226
Lower epid.	.011	.0112	.0142	.0086	.0103	.0168	.017	.0176	.0212	.017

Stems.—Cross-sections from the base of non-rayed *Cucumis* stems seven weeks old were found to have smaller diameters than any of those from rayed stems. Similar sections from the base of *Cucumis* stems in Series II A and III D were found to be a little broader, while those in Series II B and III C had the

greatest diameter (table viii). Series II B had the thickest leaves and the greatest growth in height. All rayed *Cucumis* stems in Series II and III also showed larger bundles than control stems, though there was little difference between the different rayed groups. The average width of the rayed bundles from the outside of the stem toward the center was 0.54 mm. and that of similar control bundles was 0.36 mm. The amount of bast tissue was about the same for control as for rayed stems.

Cross-sections from the base of stems of control *Nicotiana* plants were also found to be smaller in diameter than most of the rayed ones. Series II A developed stems a little smaller in diameter than those of the control plants. Stems in Series II B and III C were larger in diameter, and those in Series III D were still larger. It will be remembered that this was the group of tobacco plants that showed the thickest leaves and the healthiest appearance (table viii). As to development of vascular tissue the control plants again had the thinnest vascular cylinders which were 0.36 mm. in thickness. Next in order of thickness came Series II A (0.378 mm.) followed by Series III C (0.505 mm.) and III D (0.54 mm.). The tracheae were also smallest in the control plants and largest in Series III D with Series II A, B, and III C intermediate and equal. In all cases the walls of the tracheae were thicker in rayed plants than in non-rayed ones.

When sections from the bases of rayed *Zea Mays* stems of the different series were measured, it was found that those in Series II A were a little smaller in diameter than those from the control stems. Series II B had stems a little larger and III D still larger than those in Series II B. Stems in Series III C were the largest of all. This was also the group of plants that showed the thickest leaves and the greatest growth.

There was a noticeable range of variation present in the vascular bundles of the different groups of *Zea Mays* plants. Rayed stems in Series II A showed bundles smaller than those of the control stems, both as to entire bundle and as to size of vessels, but the phloem was better developed than in control stems. Series II B showed bundles of about the same size as control stems, but here the phloem was as well developed as in Series II A and the mechanical tissue much better developed than in

either the control stems or those in Series II A. The best-developed bundles were found in Series III C. Here the phloem and mechanical tissue were very well developed. The walls of the vessels were much heavier here than in any other group of *Zea Mays* plants. The pith cells in the control plants and those in Series II A were angled, while those in Series II B and III C and D were oval in shape, showing more air-spaces. The oval pith cells were also larger than corresponding angled ones. Series III C was also found to have many more layers of cells making up the cortex than any of the other groups of *Zea Mays* plants (pl. 33, figs. 1–8, and table VIII).

When sections of *Coleus* stem from the different groups of plants were measured, it was found that the control plants again showed smaller stems than any of the rayed plants. The stems largest in diameter were found in Series II A and B. It was these two groups also that showed the greatest growth in height (table VIII). The radial diameter of the vascular bundles of the control stems was 0.495 mm., while that of Series III D was 0.612 mm., that of III C, 0.62 mm., and of Series II B, 0.675 mm. This corresponds well with the fact that greatest growth in height was found in this group. Bast tissue was present about equally in all rayed and control stems of *Coleus*.

Sections of *Phaseolus* also showed the control plants to have stems smaller in diameter than any of the rayed plants. Series II A has stems having the greatest diameter. It will be remembered that this group of *Phaseolus* plants also showed the thickest leaves. Series III C had stems just a little smaller in diameter than those in Series II A (table VIII). When the

TABLE VIII

SHOWING THICKNESS IN MILLIMETERS OF RAYED AND NON-RAYED STEMS

Plant	Series II		Series III		Control
	A	B	C	D	E
Cucumis	5.0	5.5	5.5	5.0	4.0
Nicotiana	8.8	9.5	9.5	10.0	8.5
Zea Mays	8.0	8.8	10.7	9.5	8.5
Coleus	6.0	6.0	5.5	5.5	4.8
Phaseolus	3.8		3.5		3.0

vascular cylinder in the different rayed groups was compared it was found to be by far the thickest in Series II A and III C, averaging 0.54 mm. in diameter, while that of the control stems averaged 0.49 mm.

PHYSIOLOGICAL

Chlorophyll decomposition.—A medium green 80 per cent alcoholic chlorophyll solution was made from *Nicotiana* leaves and put in test-tubes of pure fused silica. These were placed horizontally in white dishes and exposed to the different conditions, with results given in table IX.

TABLE IX

SHOWING THE AMOUNT OF TIME NEEDED TO DECOLORIZE CHLOROPHYLL SOLUTION

	9 a.m.	12 m.
Sunlight in greenhouse	12 min.	6 min.
Sunlight outside	4 min.	2 min.
Diffused light in greenhouse	35 min.	18 min.
At 30 inches from an unscreened lamp in diffused light	39 min.	20 min.
Ultra-violet lamp screened with vita glass plus diffused light	40 min.	22 min.
Sunlight outside under a screen of vita glass	6 min.	3 min.
Sunlight outside under a screen of quartz-lite glass	5 min.	2½ min.

These results show plainly that ultra-violet rays do not hasten the decomposition of chlorophyll. Vita glass is thicker than quartz-lite, and hence used at close range the difference in thickness would account for the longer time required for the decomposition under vita glass in sunlight.

Starch storage.—Sections of *Coleus* stem at the end of seven weeks showed more starch in control plants than in any of the plants rayed as in Series II and III. It was impossible, however, to distinguish between the different rayed stems.

In sections of *Phaseolus* stem starch was present in the cortex of plants rayed as in Series II A, while similar control plants showed very little if any starch in the cortex.

Determination of P_H.—*Lactuca* plants under experiment for eight weeks as in Series I F were used for this work, the leaves and stems being determined separately. The P_H of the leaves and stems of both rayed and control plants was found to be 6.0.

The P_H of leaves and roots of *Raphanus* was determined sepa-

rately, and here again the rayed and control plants responded alike, that of the leaves being 6.2 and the roots 6.0. Thus raying with ultra-violet rays seems to have no effect on the P_H of plants.

Dry weights.—In the experiments carried on in 1926 to 1927 as described in Series I, which consisted of plants rayed with an unscreened lamp, dry weight determinations were made of the entire tops of *Lactuca* and both tops and roots of *Raphanus*. In all cases greater dry weight was found in the control plants. This can be well seen in the results in table x (a) and (b).

TABLE X

SHOWING IN GRAMS THE DRY WEIGHT OF PLANTS IN SERIES I H (50 INCHES), F (100 INCHES), AND G (CONTROL)

(a) Raphanus

	4 weeks		4 weeks		8 weeks	
	H	G	F	G	F	G
Tops	.36	.69	.326	.49	.586	1.0
Roots	.41	.79	.126	.174	.24	.496

(b) Tops of Lactuca plants

	2 leaves		9 leaves		2 leaves		9 leaves	
	H	G	H	G	F	G	F	G
4 weeks	.018	.244	.805	2.22	.116	.24	.81	1.24
8 weeks	.003	.770	.825	3.85	.200	1.15	1.56	2.76

In the experiments carried on in 1927 to 1928 the dry weight was determined for fifty grams of wet weight of leaves.

Rayed *Zea Mays* plants of Series II and III showed greater dry weight than corresponding control plants. Series II A showed the smallest dry weight of the rayed plants which was where the poorest growth in rayed plants of Series II and III was found.

Lactuca plants in Series III D had the greatest dry weight. Those in Series II A and III C showed smaller dry weight than the control plants.

Ipomoea plants in Series III D had the greatest dry weight. It was also in this group that greatest growth and thickest leaves were found.

Nicotiana plants showed greatest dry weight in the control plants and the smallest in Series II A.

Cucumis plants had the smallest dry weight in Series II B, and in this group were the greatest growth and thickest leaves with the largest air-spaces.

Phaseolus plants in Series II A showed the greatest dry weight and also the thickest leaves.

Plants of *Raphanus* showed the greatest weight in Series III C and D and the next greatest in the control plants.

Bryophyllum plants also had the greatest dry weight in Series III C and D, though all rayed plants in Series II and III had greater weights than similar control plants. A comparison of the dry weights of the various plants will be found in table XI.

TABLE XI

SHOWING THE DRY WEIGHT IN GRAMS PER FIFTY GRAMS OF WET WEIGHT OF PLANTS IN SERIES I (RAYED WITHOUT A SCREEN), SERIES II (SCREEN OF VITA GLASS) AND SERIES III (SCREEN OF QUARTZ-LITE GLASS)

Plant	Series I	Series II		Series III		Control
	H	A	B	C	D	E
Zea Mays	6.0331	5.462	6.1496	5.8290	5.9232	5.2030
Lactuca	3.1950	2.2307	2.8396	2.3322	3.2320	2.7959
Ipomoea		7.4775	7.0642	7.6735	7.7290	7.3554
Nicotiana		5.3150	5.5130	5.9240	5.9675	6.3225
Cucumis		4.8072	4.5494	4.7149	4.7544	4.8420
Phaseolus		6.9050		5.3994		6.3695
Raphanus		3.8845	3.9775	4.3200	4.3410	4.1361
Bryophyllum	2.8295	3.5100	3.4055	4.2975	3.7585	3.5286

Ash determination.—The results were not conclusive, but they point toward an increase in ash in plants rayed with an unscreened lamp. In plants rayed with a screened lamp the ash was, in the majority of cases, less than in the control plants. In *Cucumis* plants showing best growth there was less ash and also smaller dry weight than in the control plants. This can be explained, however, by the presence of many large air-spaces in those leaves while in the control leaves the air-spaces were smaller.

In *Phaseolus* the amount of ash again corresponded very well with the dry weights, there being the greatest dry weight where there was the greatest amount of ash. This also corresponded with the thickness of the leaves. For comparison of the results see table XII.

TABLE XII

SHOWING THE WEIGHT IN GRAMS OF ASH FOR 3 GRAMS OF DRY LEAF MATERIAL

Plant	A	B	C	D	E	F
Zea Mays	.310	.272	.269	.295	.325	.349
Lactuca	.600	.610	.611	.581	.595	.565
Ipomoea	.410	.302	.395	.392	.505	
Nicotiana	.527	.533	.505	.515	.570	
Cucumis	.562	.521	.505	.530	.599	
Phaseolus	.464		.435		.455	
Raphanus	.638	.630	.643	.558	.789	
Bryophyllum	.564	.5193	.482	.430	.540	.610

The effect of ultra-violet radiation upon transpiration.—When leaves of *Phaseolus*, *Cucumis*, *Lactuca* and *Coleus* were placed in bottles of water, sealed with paraffin, and rayed at 50 inches from the unscreened lamp, it was found through weighings taken every 30 minutes of bottles and leaves combined that at first the rayed leaves lost as much as the controls. Then there was a time when less weight and sometimes no weight was lost by rayed leaves. After that there was a loss equalling that of the control leaves kept in darkness or in some cases surpassing it. When the stomata were examined at the end of three hours those in the rayed leaves were found to be closed, while those in the leaves kept in darkness were partly open. When the rayed and control leaves were weighed at the beginning and end of the experiment, it was found that all the rayed leaves had lost weight while the controls had remained constant (fig. 2). It will be noted that *Coleus* behaved a little differently than did the other leaves used. This might be explained by the fact that *Coleus* has stomata on the under surface only. This experiment was repeated several times with the different leaves.

The petioles of leaves of *Coleus Blumei* var. *Verschaffeltii* were paraffined and the leaves placed in a horizontal position, some being rayed on the upper side, some on both sides, and others placed in darkness, Those in darkness and those rayed on the upper surface were partly wilted at the end of twelve hours while those rayed on both sides were still turgid. When weighed, however, the leaves rayed on both sides and those upon one side only were found to have lost much more weight than the leaves kept in darkness (table XIII, and pl. 26, fig. 3).

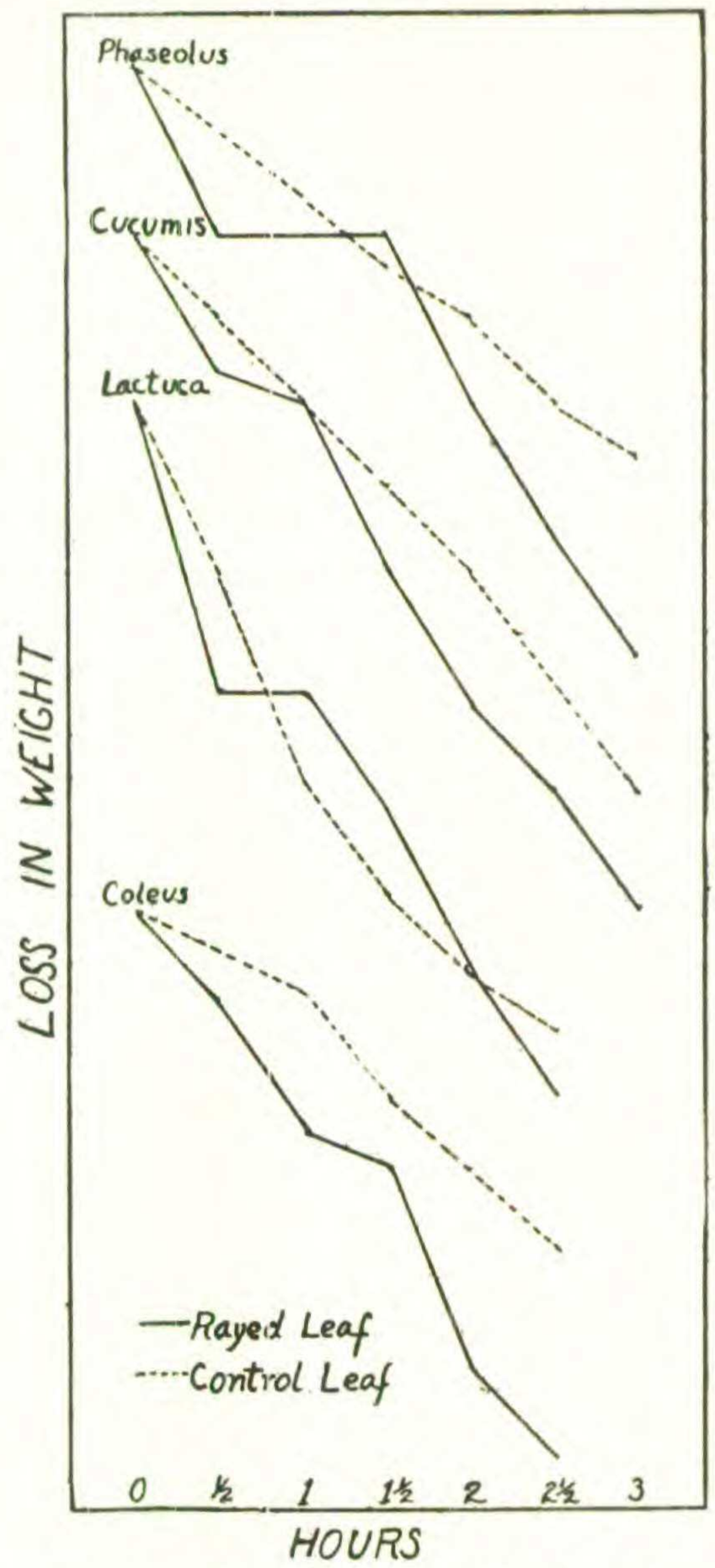

Fig. 2. Showing the comparison between the loss of weight of leaves rayed with an unscreened lamp and those kept in darkness.

TABLE XIII

SHOWING LOSS OF WEIGHT IN GRAMS OF COLEUS LEAVES WITH PARAFFINED STEMS

	Control	Rayed on both sides	Rayed on one side
Original weight	1.90	2.10	1.65
Weight after 12 hours	1.75	1.72	1.20
Loss	.15	.38	.45

DISCUSSION

Several points have been very clearly brought out by the foregoing experiments. All plants rayed with an unscreened

quartz mercury lamp were conspicuously injured. At a distance of 50 inches from such a lamp the injury was very great to all plants. At 100 inches away the injury was not so great for the same length of exposure, probably due to a portion of the injurious rays being absorbed by the atmosphere between the lamp and the plant. It was also evident that at this distance some plants were more resistant to ultra-violet radiation as a whole than others and that younger plants were less resistant than older ones. The latter fact was particularly noticeable in *Lactuca* where the growth of young plants was almost completely stopped while that of older ones was only retarded.

The injury was first evident in the epidermis where many of the cells if not collapsed, forming a false cuticle, were smaller than those of control leaves. After raying for a period of weeks, the injury to newly formed leaves was evident through the entire leaf, causing the mesophyll tissue to be more compact with fewer air-spaces and with little differentiation between the different kinds of cells. In plants such as *Raphanus* the contents of the palisade cells were drawn away from the upper ends of the cells, particularly in regions where the epidermis had collapsed. These results suggest that raying with an unscreened lamp may actually retard growth in individual cells even if it does not kill them.

Bailey ('94), using an open arc lamp, and Kluyver ('11), Ritson and Westbrook (Delf, Ritson and Westbrook, '27), using quartz mercury vapor lamps, obtained similar results though different methods of raying were used in all cases. Bailey and Kluyver found anthocyanin disappearing from rayed *Coleus* leaves when the color was present in the epidermis only.

In the foregoing experiments when *Coleus* was rayed under the same general conditions, the anthocyanin pigment disappeared also from the palisade cells of the leaves and from the entire stem tips.

Until recently the penetration of the short ultra-violet rays was thought to be very slight. In fact a layer of skin was said to inhibit their passage. Macht, Anderson, and Bell ('28), however, using living anesthetized animals have shown that rays as short as 313 $\mu\mu$ penetrate into the peritoneal cavity of a rabbit.

Therefore it might not be unusual for rays to penetrate through plant epidermis into the palisade cells or into the cortex of a stem tip, either destroying the pigment or preventing its formation. Green ('97) has suggested that chlorophyll might act as a screen absorbing injurious rays. This supposition is strengthened by the results of experiments on chlorophyll in this paper where ultra-violet rays were found to have very little, if any, effect upon chlorophyll decomposition. If there is a screening action of chlorophyll, it might not have been evident here due to the small number of chloroplastids present in the cortex of the stem. On the other hand, the rays might not have penetrated deep enough to cause direct action, but may have set up chemical reaction which induced the decomposition of anthocyanin or prevented its formation.

Sheard and Higgins ('27) found that in general rays of 270 to 320 μμ delayed the time of germination and lessened the rate of growth, but that rays of 320–390 μμ were effective in promoting growth.

In the experiments in this paper where the lamp was screened by vita glass which cut out rays below 290 μμ, there were no lesions though the newly formed leaves of *Lactuca*, *Raphanus*, and *Coleus* were thinner. In the other plants used the leaves were either of the same or greater thickness than control leaves.

When the lamp was screened by quartz-lite glass which cut out rays shorter than 310 μμ there was also no evidence of lesions though the same three plants again had thinner leaves, while all others had much thicker leaves than the control plants.

In nearly all cases where leaves were found to be thicker when rayed by a screened lamp, the plants themselves were found to be taller with larger stems and more numerous leaves. In no cases was flower production retarded, and in *Cucumis* and *Phaseolus* it was slightly increased.

Sometimes the increase in size took the form of more numerous and larger air-spaces with only slightly larger cells. This was true of both the stems and leaves of *Cucumis* and *Nicotiana* and of the stems of *Zea Mays*. In other cases there were more air-spaces but when this occurred the palisade cells were very much larger. This was very noticeable in *Ipomoea* and *Phaseolus*. In

the leaves of *Zea Mays* the increased growth was evident only in the form of larger cells.

Coleus plants rayed with a lamp screened by vita glass or quartz-lite glass showed a marked increase in growth over control plants, though the thickness of the leaves was inversely proportional to their increase in height and number. This might indicate incipient injury to the leaves with a possible stimulatory effect upon the plant as a whole. In addition there was no loss of red color here as there had been when an unscreened lamp was used.

The results with the use of screens correspond well with those of McCrea ('27), where increased growth was obtained in *Digitalis* by the use of vita glass instead of ordinary glass in a greenhouse, and with those of Tsuji ('18), who produced larger and juicier pineapples by raying them in the field with a weak ultra-violet lamp.

When *Phaseolus* plants with both cotyledons removed were rayed either by a screened or an unscreened lamp there was a retardation in growth compared with corresponding non-rayed plants. When only one cotyledon was removed from *Phaseolus* plants, raying with a screened lamp produced a slight increase in growth over corresponding non-rayed plants. This compares well with the work of Westbrook (Delf, Ritson, and Westbrook, '27) where different lengths of day were used in addition to a short daily raying with an unscreened lamp. In all cases the injury was greater the shorter the day. These results and the fact that older *Lactuca* plants were more resistant than young ones may indicate the possibility that the presence of sufficient food may at least partially overcome the injurious effects of raying.

Clement ('26) found that apples that had been rayed stayed turgid longer than non-rayed ones. Likewise Tsuji ('18) observed that stalks of banana plants that were rayed after being cut kept fresh many days longer than non-rayed ones. The writer has found that if the petioles of *Coleus* leaves were dipped in paraffin and the leaves then rayed with an unscreened lamp first on one side and then on the other for a period of one and a half hours each, they remained turgid at the end of twelve hours, while the control leaves were badly wilted. If, however, the leaves were rayed only on one side the leaves were much more

wilted than the control leaves. All these observations would tend to indicate that a false cuticle is formed wherever plant tissue is rayed heavily with ultra-violet, thus greatly retarding the rate of water loss from the internal tissues.

In the foregoing experiments, using a wide variety of plants in sufficient numbers to avoid individual differences, and using two well-known ultra-violet glasses as screens, the writer has reached the conclusion that increased growth can be obtained in many groups of plants by the daily use of a quartz mercury vapor lamp screened to cut out the harmful short rays. However, results point to the supposition that each variety of plant has its own ultra-violet requirement for best growth and that this can be determined only by experiment.

SUMMARY

1. Raying with an unscreened quartz mercury vapor lamp caused injury in all plants used.

2. Raying with a lamp screened by vita glass was beneficial for some plants, while it produced little visible effect in others. When examined anatomically no lesions were present, but in some cases there was a slight retardation of growth.

3. Raying with a lamp screened by quartz-lite glass injured none and benefited many of the plants. In some cases, however, the benefit was less than when vita glass was used.

4. Except for *Raphanus* and possibly *Lactuca* the healthiest-appearing plants were among those rayed with a screened lamp, although the distance from the light and the screen promoting best growth differed for different plants.

5. Raying with a screened lamp increased flower production slightly.

6. Plants rayed for a period of weeks with an unscreened lamp developed leaves which were thinner than those of corresponding non-rayed plants, the decrease in thickness being due to a partial or complete collapse of the upper epidermal cells, a lack of differentiation of the palisade layer, and a decrease in the number and size of the air-spaces present in the mesophyll tissue.

7. With the exception of *Coleus*, *Raphanus*, and *Lactuca*, leaves of plants rayed with a screened lamp were in general thicker than

corresponding leaves from control plants, though the particular screen and distance from the lamp promoting the formation of the thickest leaves differed for different plants. The increase in thickness was due either to increase in size of cells or to increase in number and size of air-spaces or to both.

8. The stems rayed with a screened lamp were greater in diameter and contained better-developed vascular bundles than non-rayed ones.

9. A limitation of the amount of available food emphasizes the injurious effect of ultra-violet rays.

10. Ultra-violet radiation had very little, if any, effect upon the decomposition of chlorophyll and thus very little effect upon the photosynthetic apparatus.

11. Ultra-violet radiation had no effect upon the P_H of the plants used.

These results again emphasize the fact that each plant has its own ultra-violet requirement for best growth which can be determined only by experiment.

Acknowledgments

The writer wishes to express sincere appreciation to Dr. B. M. Duggar, Professor of Physiological and Applied Botany, University of Wisconsin, formerly Professor of Plant Physiology in the Henry Shaw School of Botany of Washington University, for suggesting this problem and under whose guidance the early part of this work was carried out; to Dr. E. S. Reynolds, Physiologist to the Missouri Botanical Garden, for his advice and helpful criticisms concerning the work; to Dr. C. F. Hagenow, of the Physics Department of Washington University, for spectral photographs; to Dr. LeRoy McMaster, of the Chemistry Department of Washington University, for the use of laboratory and apparatus; and to Dr. G. T. Moore, Director of the Missouri Botanical Garden, for the privileges and facilities of that institution.

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Explanation of Plate

PLATE 21 (SERIES I F, H AND G)

Fig. 1. *Cucumis sativus.*
A. Plant rayed four weeks at 100 inches from the light without a screen.
B. Plant not rayed.

Fig. 2. *Cucumis sativus.*
A. Plant not rayed.
B. Plant rayed for eight weeks as in fig. 1 A.

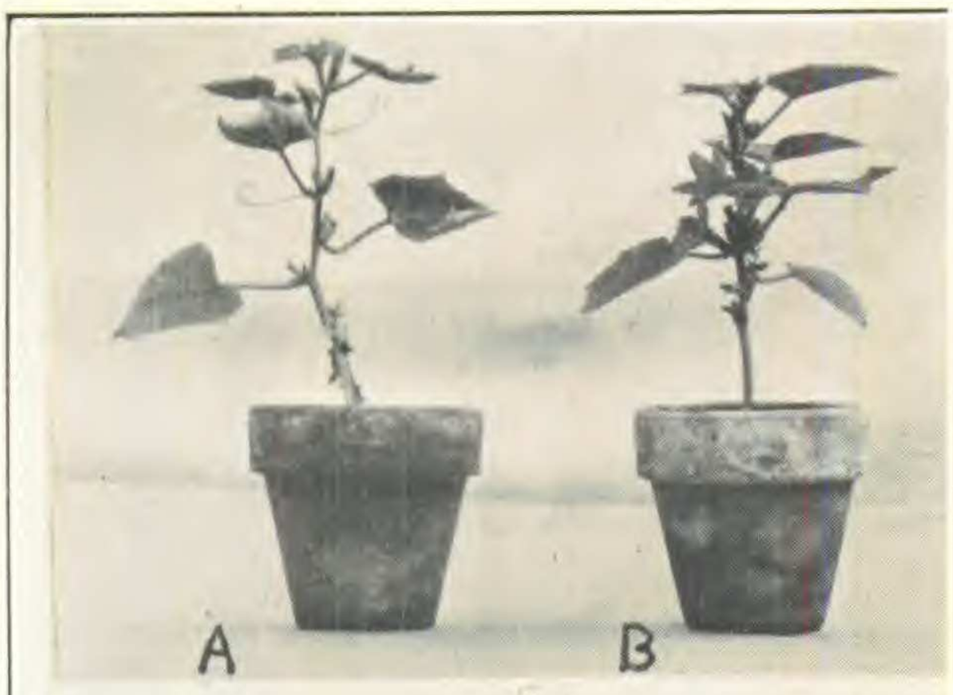
Fig. 3. *Raphanus sativus.*
A. Plants not rayed.
B. Plants rayed for eight weeks at 100 inches from the light without a screen.
C. Plants rayed for eight weeks at 50 inches from the light without a screen.

Fig. 4. *Raphanus sativus.*
A. Plant rayed for eight weeks at 100 inches as in fig. 3 B.
B. Plant not rayed.

Fig. 5. *Raphanus sativus.*
A. Plant rayed for four weeks at 100 inches as in fig. 3 B.
B. Plant not rayed.

Fig. 6. *Ipomoea Batatas.*
A. Plant rayed for eight weeks at 100 inches from the light without a screen.
B. Plant not rayed.

Fig. 7. *Raphanus sativus.*
A. Plant not rayed.
B. Plant rayed for eight weeks as in fig. 3 B.



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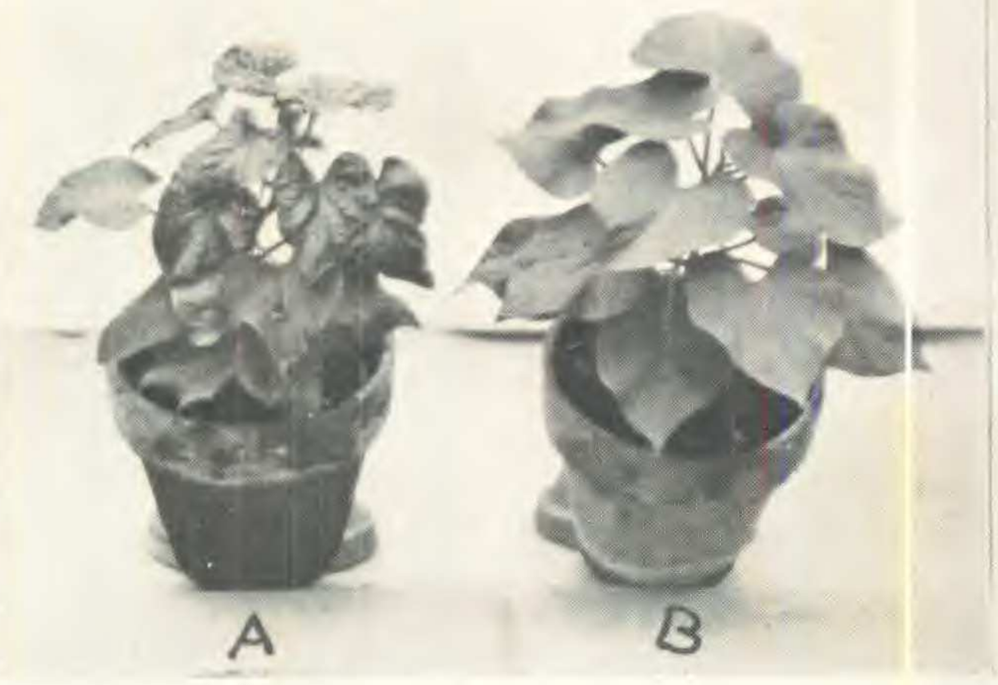

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Explanation of Plate

PLATE 22 (SERIES I H, F AND G)

Fig. 1. *Lactuca sativa* (nine leaves) rayed for four weeks.
A. Plant rayed at 50 inches from the light without a screen.
B. Plant rayed at 100 inches from the light without a screen.
C. Plant not rayed.

Fig. 2. *Lactuca sativa* (two leaves) rayed for eight weeks.
A. Plant rayed at 50 inches from the light without a screen.
B. Plant rayed at 100 inches from the light without a screen.
C. Plant not rayed.

Fig. 3. *Lactuca sativa* (two leaves) rayed for four weeks.
A. Plant rayed at 50 inches from the light.
B. Plant rayed at 100 inches from the light without a screen.
C. Plant not rayed.

Fig. 4. *Coleus Blumei* var. "Spotted Gem."
A. Plant rayed for two weeks at 50 inches from the light without a screen.
B. Plant not rayed.

Fig. 5. *Coleus Blumei* vars. *Verschaffeltii* and "Spotted Gem."
A. Var "Spotted Gem" rayed for eight weeks at 100 inches from the light without a screen and then allowed to recover in the greenhouse for four weeks.
B. Var. "Spotted Gem" not rayed.
C. Var. *Verschaffeltii* treated the same as in fig. 5 A.
D. Var. *Verschaffeltii* not rayed.

ELTINGE—EFFECT OF ULTRA-VIOLET RADIATION

Explanation of Plate

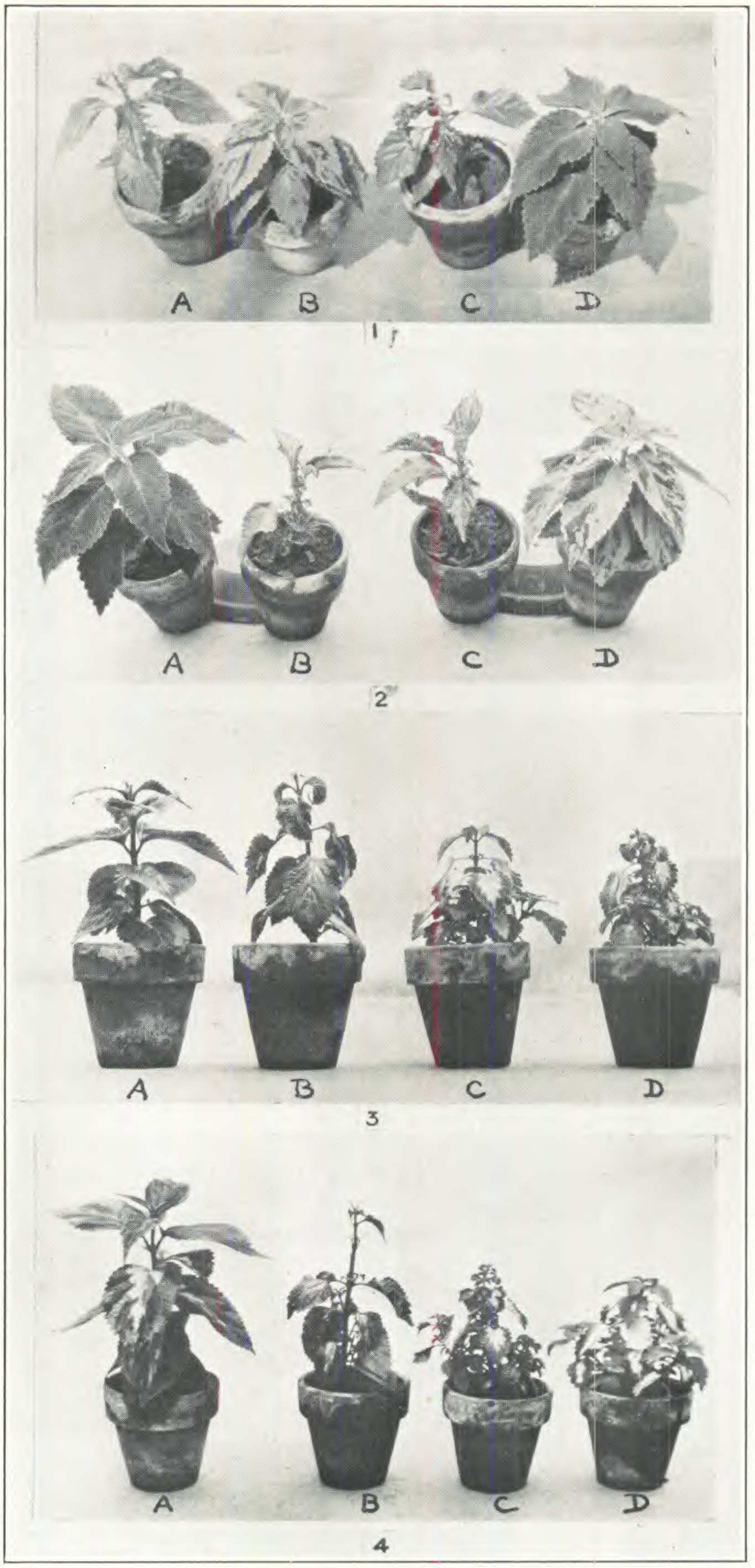
PLATE 23 (SERIES I F AND G)

Fig. 1. *Coleus Blumei* vars. "Spotted Gem" and *Verschaffeltii*.
A. Var. "Spotted Gem" rayed for four weeks at 100 inches from the light without a screen.
B. Var. "Spotted Gem" not rayed.
C. Var *Verschaffeltii* rayed under the same conditions as "Spotted Gem."
D. Var. *Verschaffeltii* not rayed.

Fig. 2. *Coleus Blumei* var. "Spotted Gem" and *Verschaffeltii*.
A. Var. *Verschaffeltii* not rayed.
B. Var. *Verschaffeltii* rayed for seven weeks at 100 inches from the light without a screen.
C. Var. "Spotted Gem" rayed for seven weeks under the same conditions as in fig. 2 B.
D. Var. "Spotted Gem" not rayed.

Fig. 3. *Coleus Blumei* var. "Defiance " and "Trailing Queen."
A. Var. "Defiance" not rayed.
B. Var. "Defiance" rayed for four weeks under the same conditions as the plants in fig. 1 A.
C. Var. "Trailing Queen" not rayed.
D. Var. "Trailing Queen" rayed for four weeks under the same conditions as fig. 1 A.

Fig. 4. *Coleus Blumei* var. "Defiance" and "Trailing Queen."
A. Var. "Defiance" not rayed.
B. Var. "Defiance" rayed for seven weeks under the same conditions as fig. 1 A.
C. Var. "Trailing Queen" rayed for seven weeks under the same conditions as fig. 1 A.
D. Var. "Trailing Queen" not rayed.



ELTINGE—EFFECT OF ULTRA-VIOLET RADIATION

Explanation of Plate

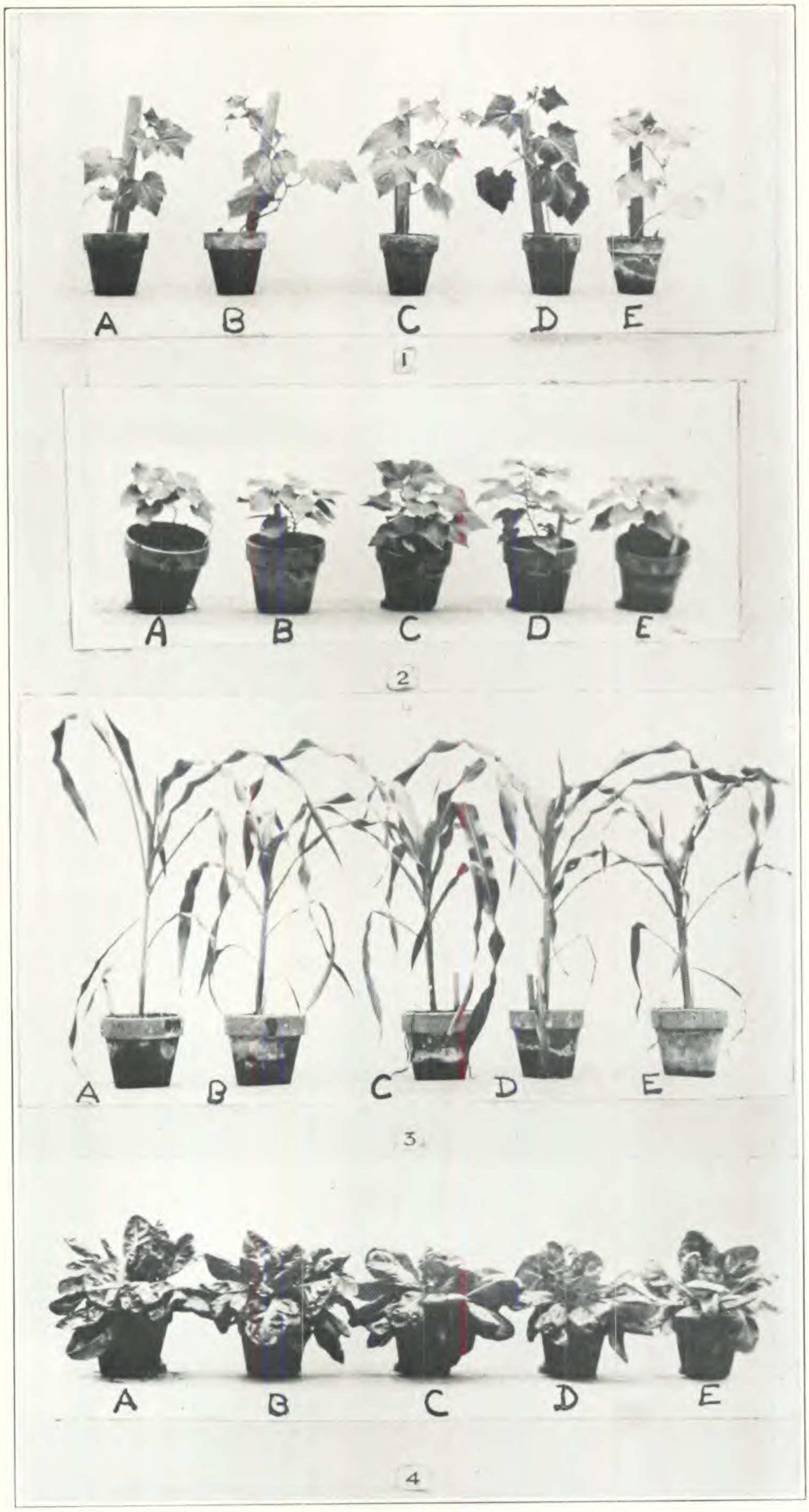
PLATE 24 (SERIES II AND III)

Fig. 1. *Cucumis sativus.*
A. Plant not rayed.
B. Plant rayed for seven weeks at 100 inches, using a screen of quartz-lite glass.
C. Plant rayed for seven weeks at 50 inches, using a screen of quartz-lite glass.
D. Plant rayed for seven weeks at 100 inches, using a screen of vita glass.
E. Plant rayed for seven weeks at 50 inches, using a screen of vita glass.

Fig. 2. *Ipomoea Batatas.*
A. Plant not rayed.
B. Plant rayed for seven weeks at 100 inches, using a screen of quartz-lite glass.
C. Plant rayed for seven weeks at 50 inches, using a screen of quartz-lite glass.
D. Plant rayed for seven weeks at 100 inches, using a screen of vita glass.
E. Plant rayed for seven weeks at 50 inches, using a screen of vita glass.

Fig. 3. *Zea Mays.*
A. Plant not rayed.
B. Plant rayed for seven weeks at 100 inches, using a screen of quartz-lite glass.
C. Plant rayed for seven weeks at 50 inches, using a screen of quartz-lite glass.
D. Plant rayed for seven weeks at 100 inches, using a screen of vita glass.
E. Plant rayed for seven weeks at 50 inches, using a screen of vita glass.

Fig. 4. *Lactuca sativa.*
A. Plant not rayed.
B. Plant rayed for seven weeks at 100 inches, using a screen of quartz-lite glass.
C. Plant rayed for seven weeks at 50 inches, using a screen of quartz-lite glass.
D. Plant rayed for seven weeks at 100 inches, using a screen of vita glass.
E. Plant rayed for seven weeks at 50 inches, using a screen of vita glass.



ELTINGE—EFFECT OF ULTRA-VIOLET RADIATION

Explanation of Plate

PLATE 25 (SERIES II AND III)

Fig. 1. *Raphanus sativus.*
A. Plant not rayed.
B. Plant rayed for seven weeks at 100 inches from the light, using a screen of quartz-lite glass.
C. Plant rayed for seven weeks at 50 inches from the light, using a screen of quartz-lite glass.
D. Plant rayed for seven weeks at 100 inches from the light, using a screen of vita glass.
E. Plant rayed for seven weeks at 50 inches from the light, using a screen of vita glass.

Fig. 2. *Coleus Blumei* var. "Spotted Gem."
A. Plant rayed for seven weeks at 50 inches from the light, using a screen of vita glass.
B. Plant rayed for seven weeks at 100 inches from the light, using a screen of vita glass.
C. Plant rayed for seven weeks at 50 inches from the light, using a screen of quartz-lite glass.
D. Plant rayed for seven weeks at 100 inches from the light, using a screen of quartz-lite glass.
E. Plant not rayed.

Fig. 3. *Coleus Blumei* var. *Verschaffeltii.*
A. Plant rayed for seven weeks at 50 inches from the light, using a screen of vita glass.
B. Plant rayed for seven weeks at 100 inches from the light, using a screen of vita glass.
C. Plant rayed for seven weeks at 50 inches from the light, using a screen of quartz-lite glass.
D. Plant rayed for seven weeks at 100 inches from the light, using a screen of quartz-lite glass.
E. Plant not rayed.

Fig. 4. *Bryophyllum pinnatum.*
A. Plant rayed for seven weeks at 50 inches from the light, using a screen of vita glass.
B. Plant rayed for seven weeks at 100 inches from the light, using a screen of vita glass.
C. Plant rayed for seven weeks at 50 inches from the light, using a screen of quartz-lite glass.
D. Plant rayed for seven weeks at 100 inches from the light, using a screen of quartz-lite glass.
E. Plant not rayed.

ELTINGE—EFFECT OF ULTRA-VIOLET RADIATION

Explanation of Plate

PLATE 26

Fig. 1. *Lactuca sativa* (fifteen leaves).
A. Plant rayed for eight weeks at 100 inches from an unscreened lamp.
B. Plant not rayed.

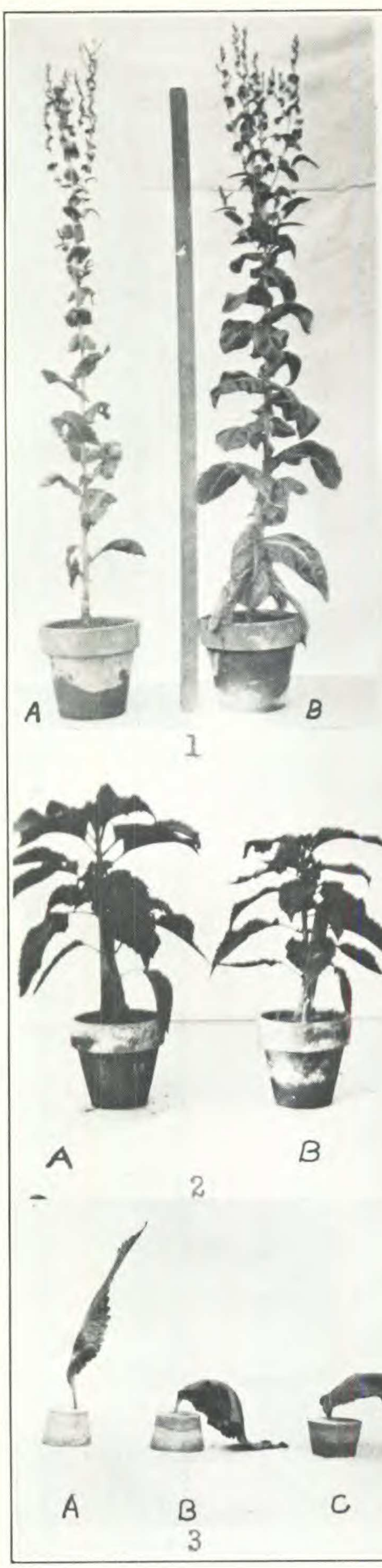
Fig. 2. *Coleus Blumei* var. *Verschaffeltii*.
A. Plant rayed for thirty seconds each day at 100 inches from an unscreened lamp.
B. Plant not rayed.

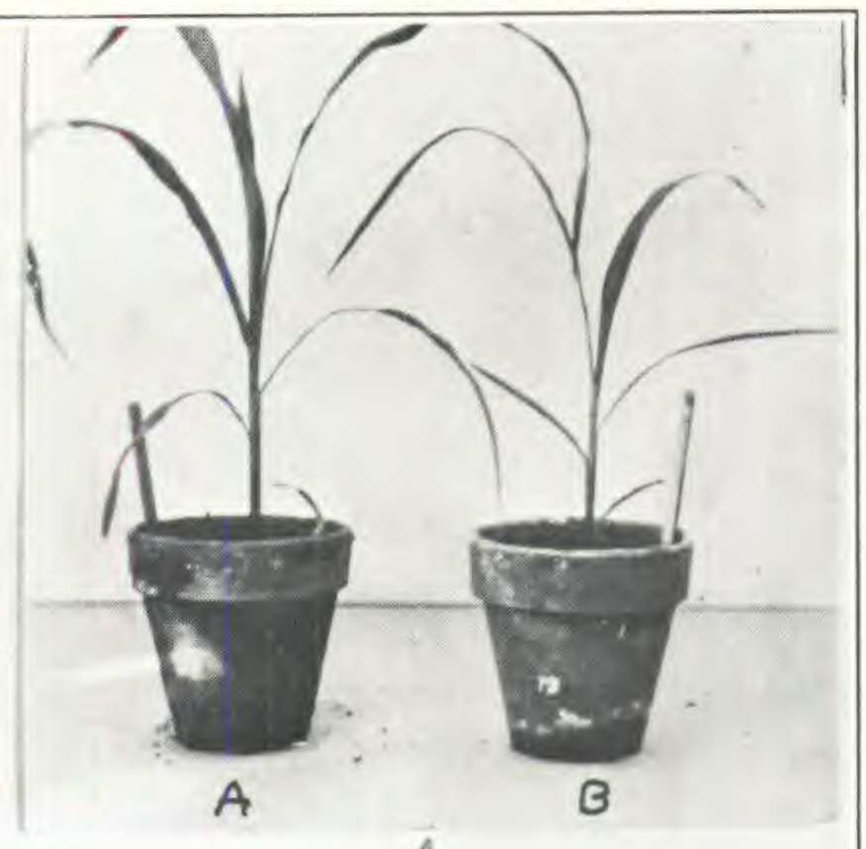
Fig. 3. Leaves of *Coleus Blumei* var. *Verschaffeltii*, with petioles paraffined.
A. Leaf twelve hours after it had been rayed for 1½ hours on each surface at thirty inches from an unscreened lamp.
B. Leaf twelve hours after it had been rayed for 1½ hours upon the upper surface at thirty inches from an unscreened lamp.
C. Unrayed leaf after twelve hours.

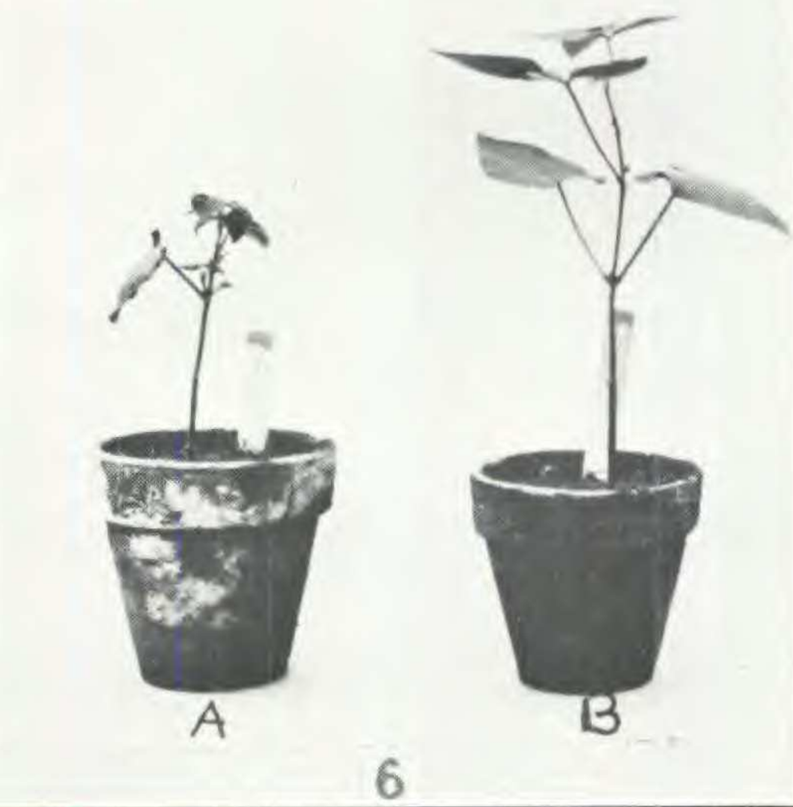
Fig. 4. *Zea Mays*.
A. Plant not rayed.
B. Plant rayed for six weeks at 100 inches from an unscreened lamp.

Fig. 5. *Bryophyllum pinnatum*.
A. Plant not rayed.
B. Plant rayed for six weeks at 100 inches from an unscreened lamp.

Fig. 6. *Phaseolus vulgaris*.
A. Plant rayed for four weeks at 100 inches from an unscreened lamp.
B. Plant not rayed.







ELTINGE—EFFECT OF ULTRA-VIOLET RADIATION

Explanation of Plate

PLATE 27

Camera-lucida drawings of equal magnification, using 4-mm. objective and 10 × eyepiece.

Fig. 1. Leaf of *Lactuca sativa* not rayed.

Fig. 2. Leaf of *Lactuca sativa* rayed for four weeks at 100 inches from the light without a screen.

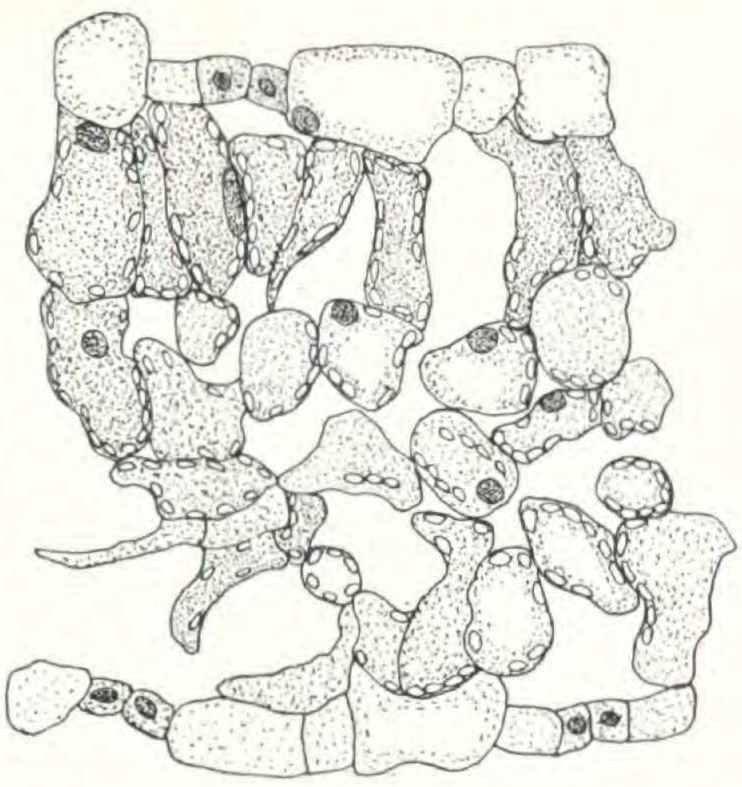
Fig. 3. Leaf of *Lactuca sativa* rayed for eight weeks at 100 inches from the light without a screen.

Fig. 4. Leaf of *Lactuca sativa* rayed for four weeks at 50 inches from the light without a screen.

Fig. 5. Leaf of *Nicotiana Tabacum* rayed for seven weeks at 100 inches from the light, using a screen of quartz-lite glass.

Fig. 6. Leaf of *Nicotiana Tabacum* not rayed.

Fig. 7. Leaf of *Nicotiana Tabacum* rayed for four weeks at 50 inches from the light without a screen.



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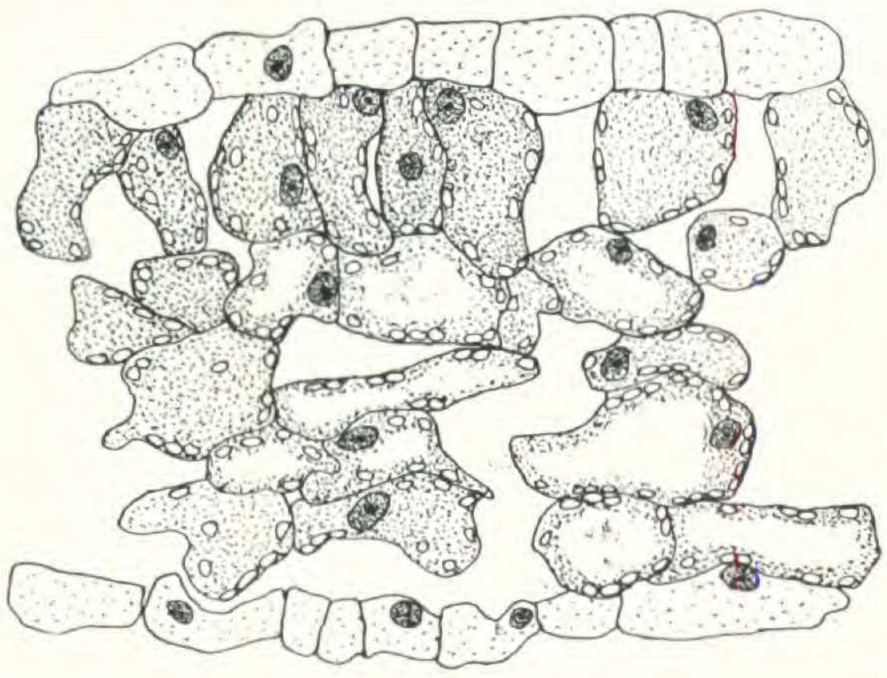

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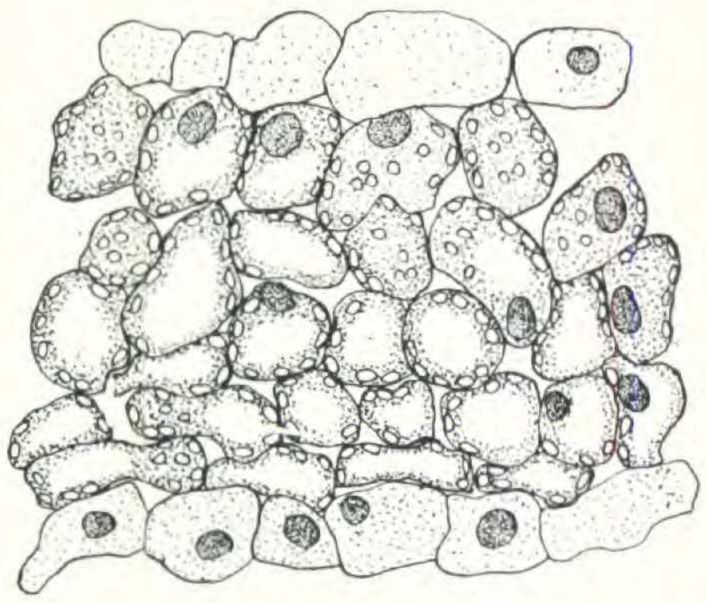

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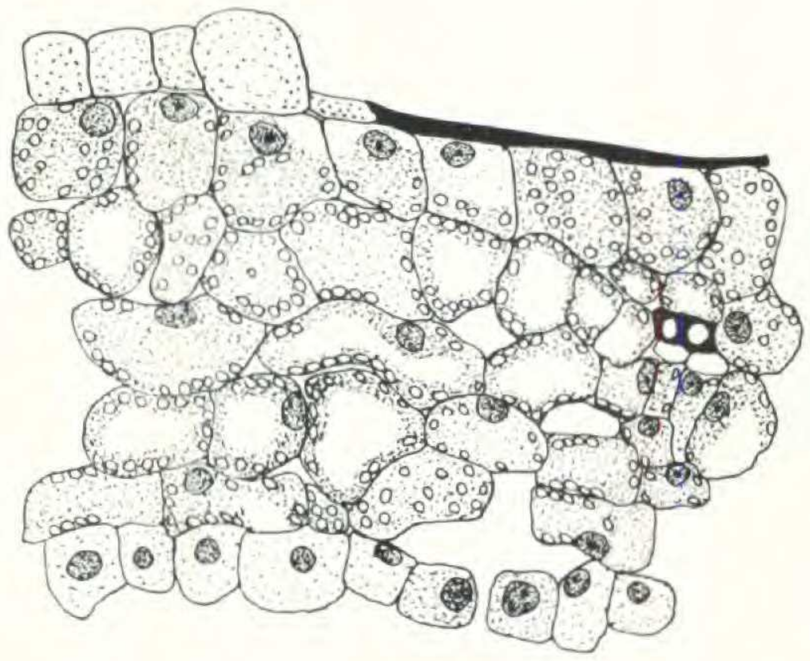

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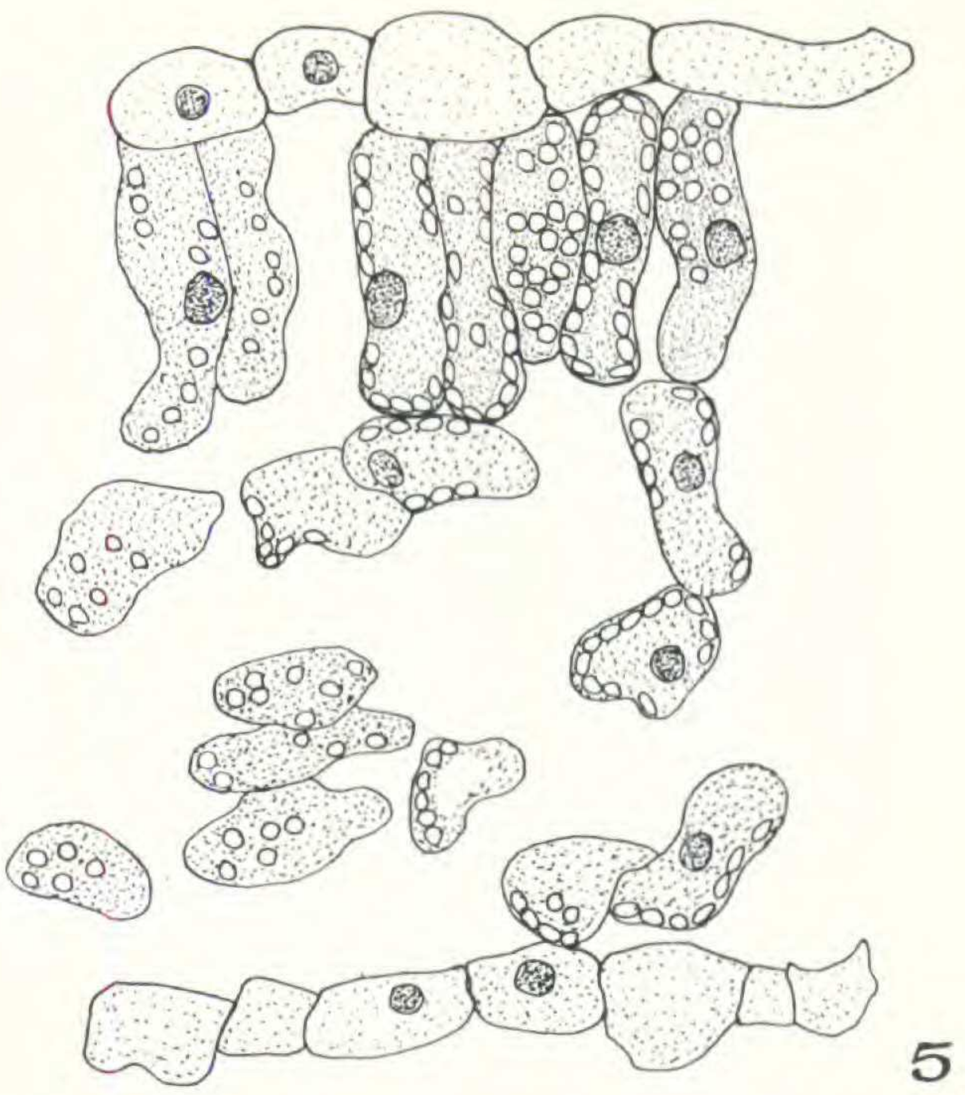

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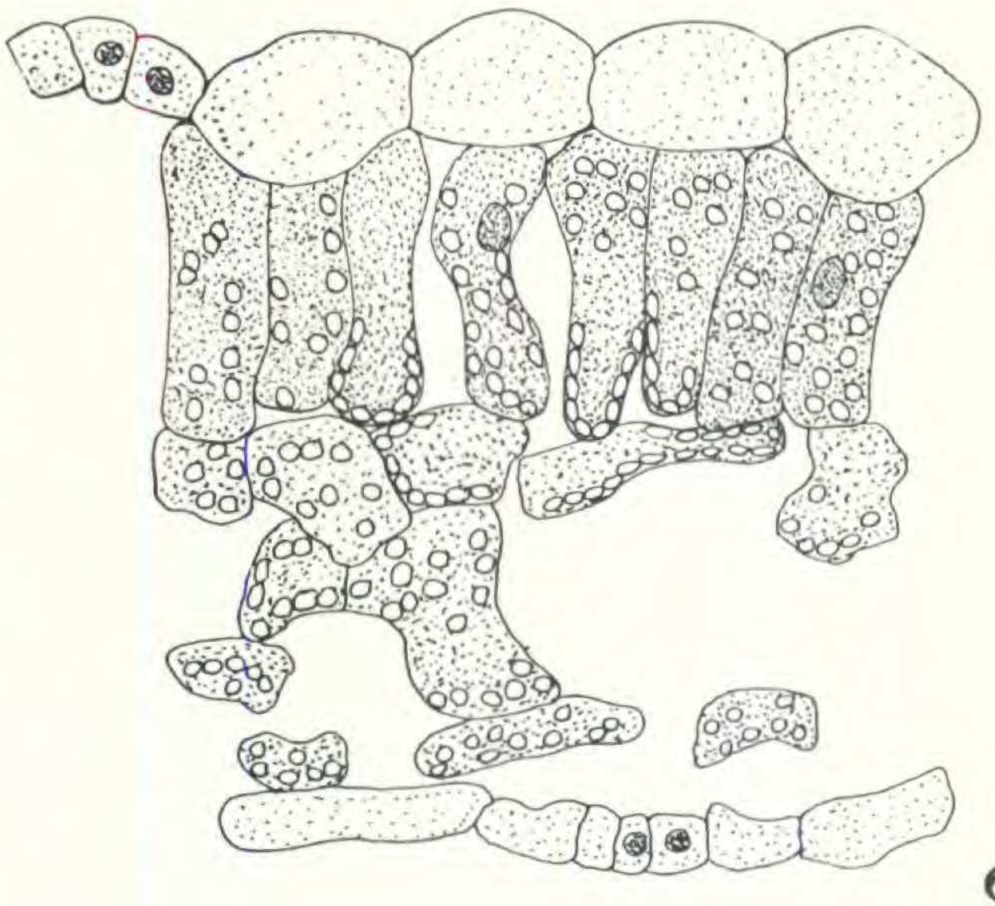

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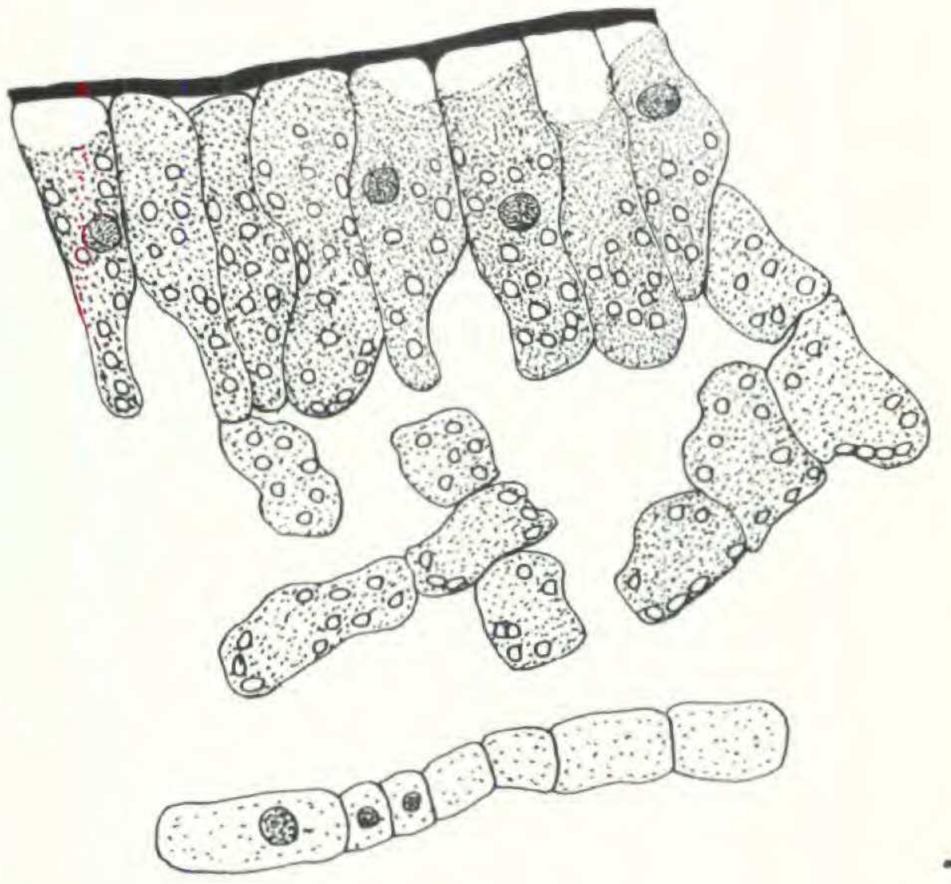

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ELTINGE—EFFECT OF ULTRA-VIOLET RADIATION

Explanation of Plate

PLATE 28

Camera-lucida drawings of equal magnification, using 4-mm. objective and 10 × eyepiece.

Fig. 1. Leaf of *Phaseolus vulgaris* not rayed.

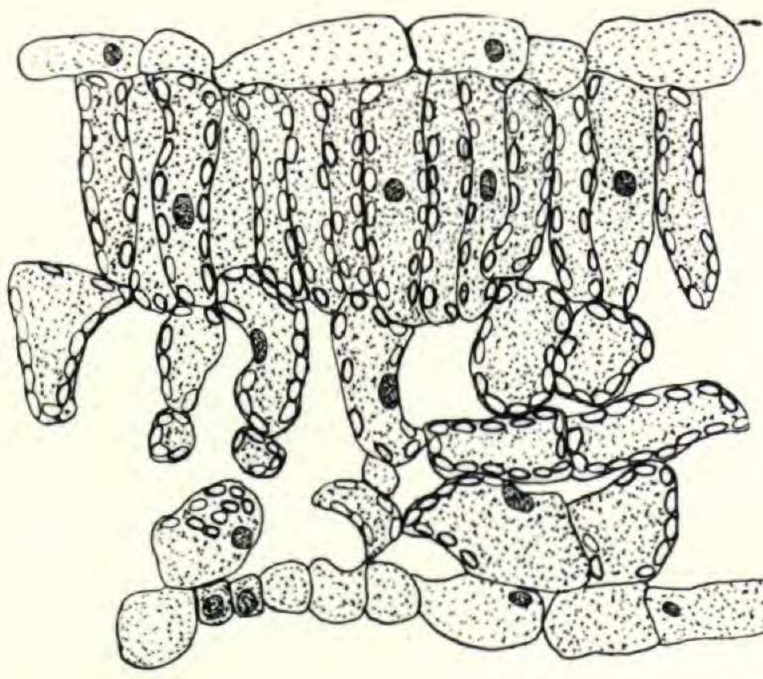
Fig. 2. Leaf of *Phaseolus vulgaris* rayed for four weeks at 100 inches from the light without a screen.

Fig. 3. Leaf of *Phaseolus vulgaris* rayed for seven weeks at 50 inches from the light, using a screen of quartz-lite glass.

Fig. 4. Leaf of *Cucumis sativus* not rayed.

Fig. 5. Leaf of *Cucumis sativus* rayed for four weeks at 100 inches from the light without a screen.

Fig. 6. Leaf of *Phaseolus vulgaris* rayed for seven weeks at 50 inches from the light, using a screen of vita glass.



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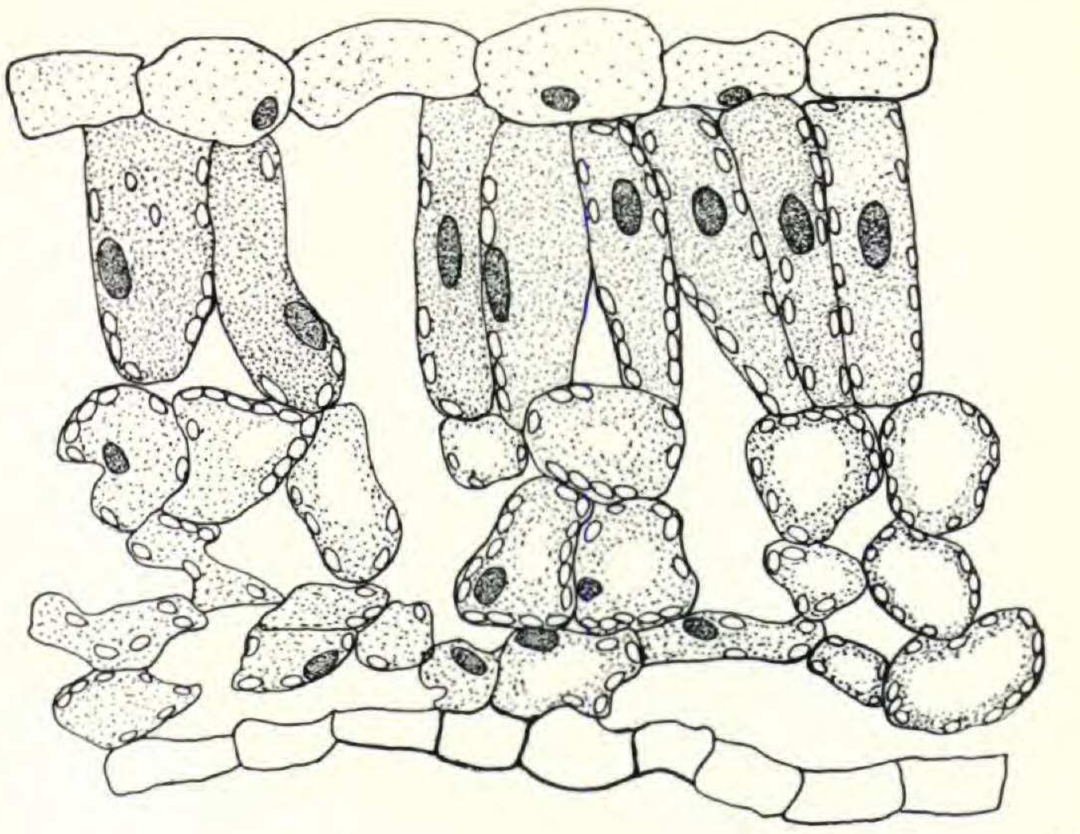

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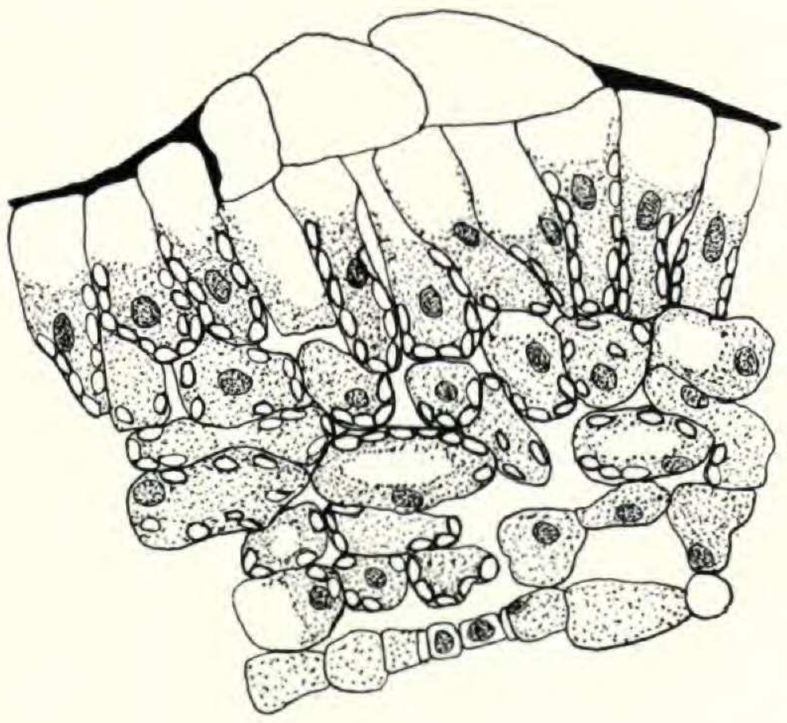

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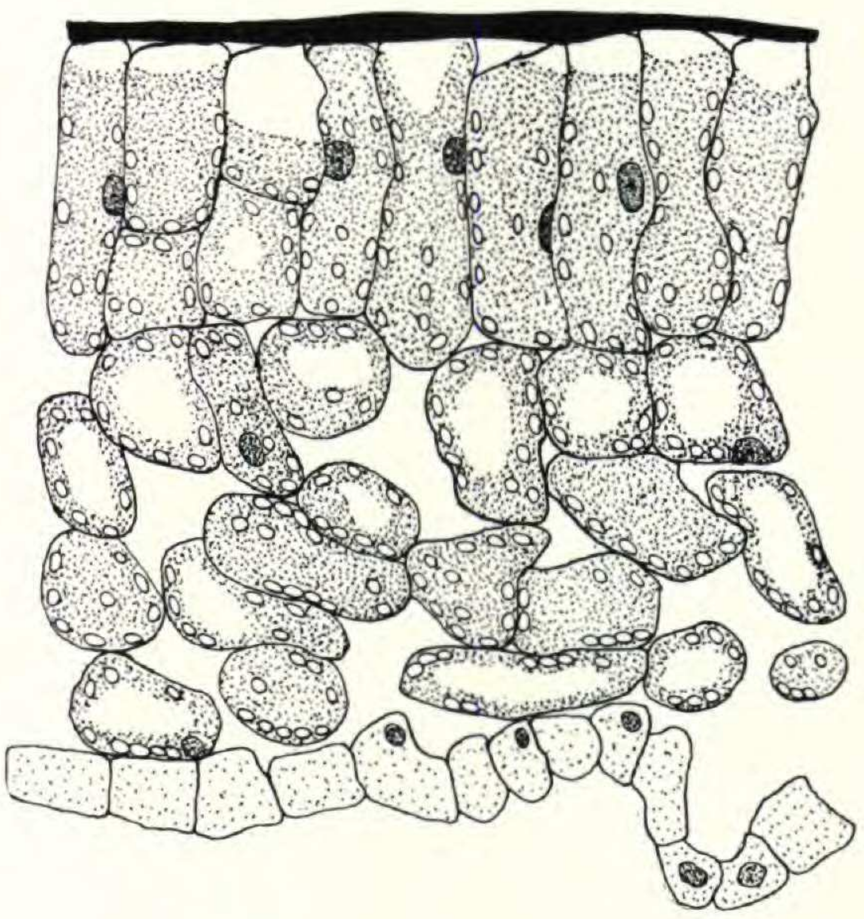

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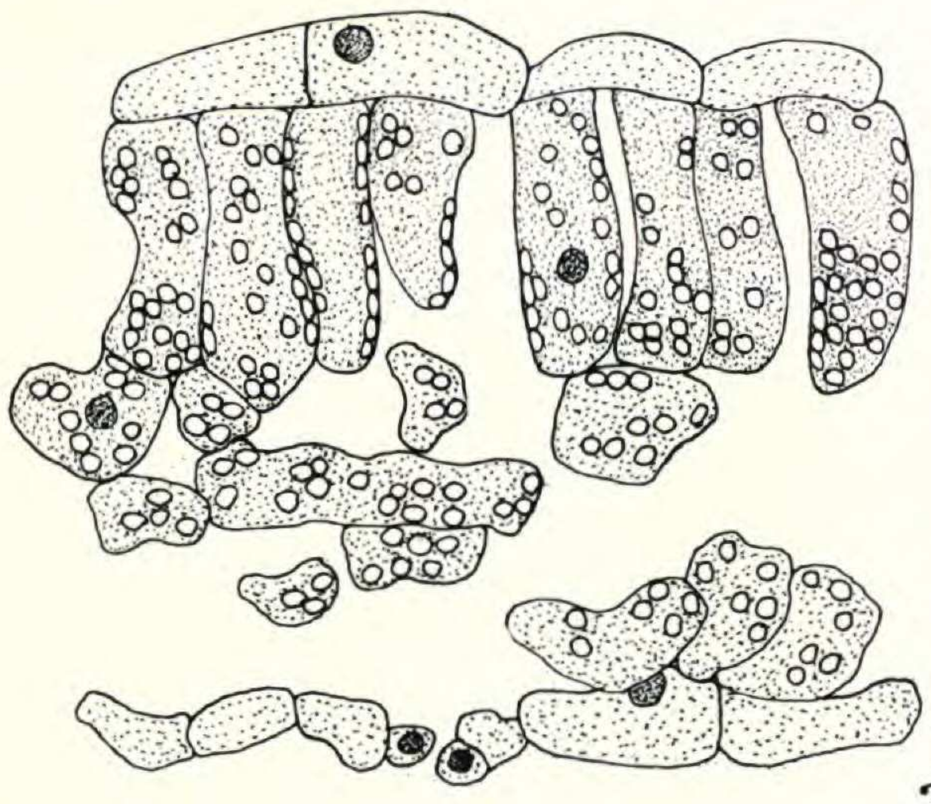

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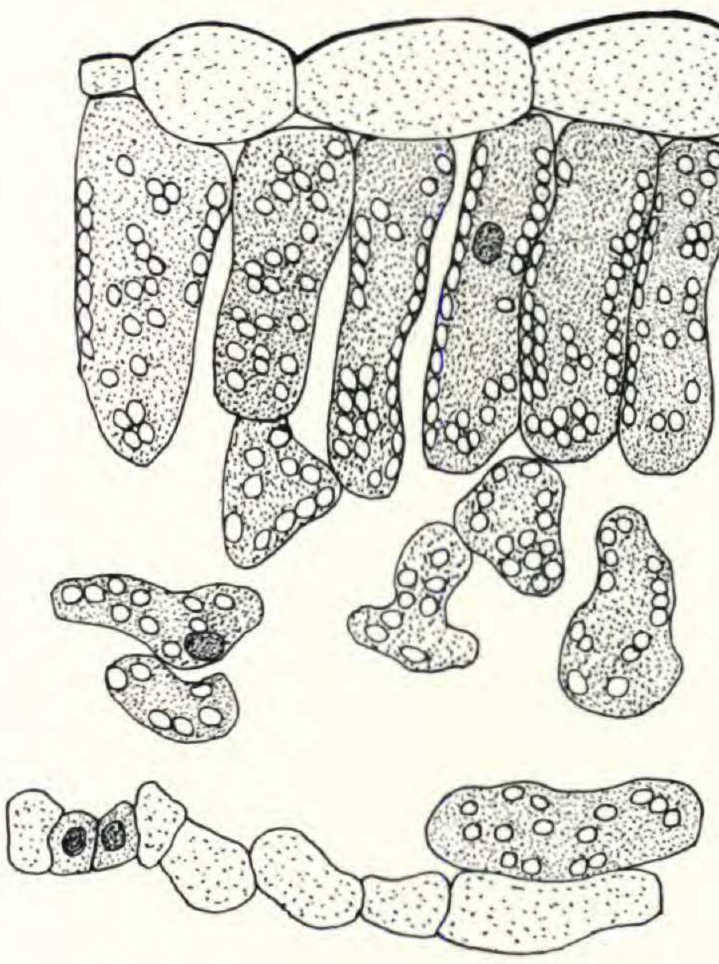


6

ELTINGE—EFFECT OF ULTRA-VIOLET RADIATION

Explanation of Plate

PLATE 29

Camera-lucida drawings of equal magnification, using 4-mm. objective and 10 × eyepiece.

Fig. 1. Leaf of *Cucumis sativus* unrayed.

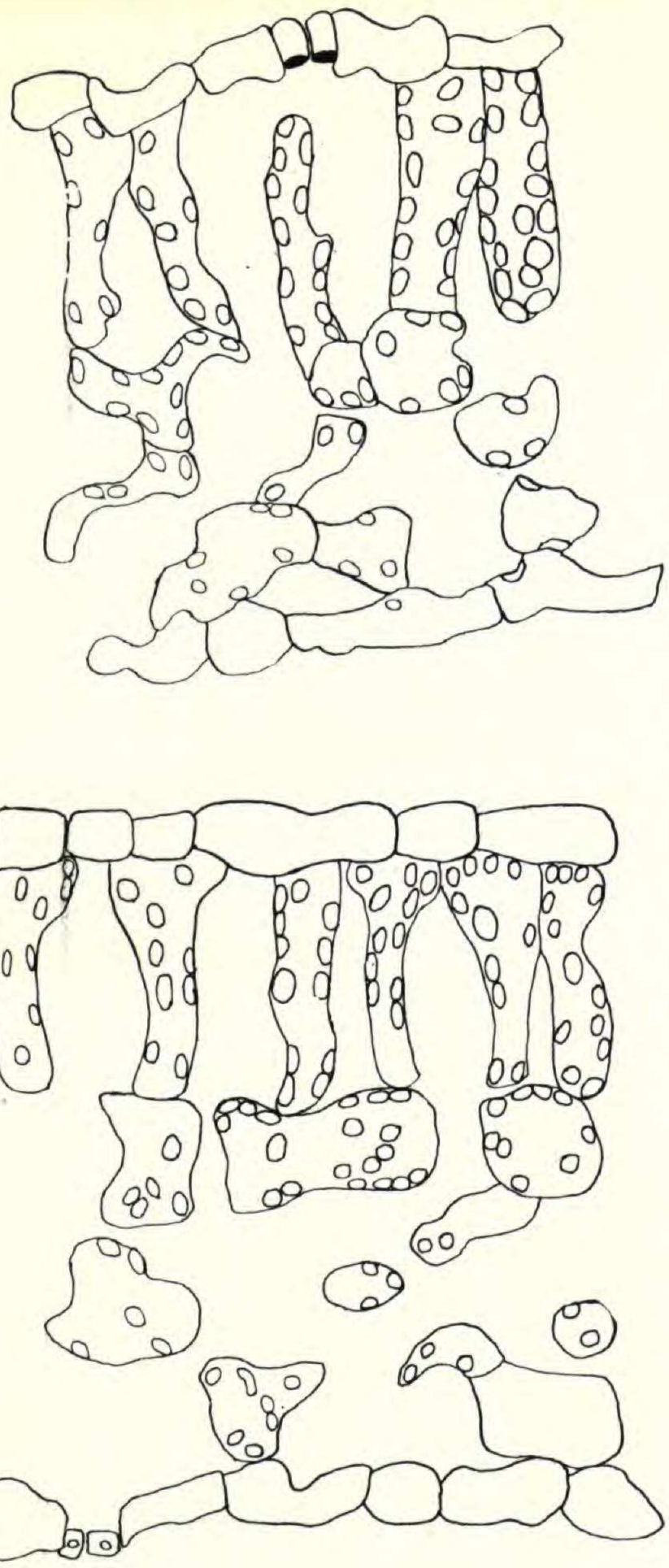
Fig. 2. Leaf of *Cucumis sativus* rayed for seven weeks at 100 inches from the light, using a screen of vita glass.

Fig. 3. Leaf of *Cucumis sativus* rayed for seven weeks at 100 inches from the light, using a screen of quartz-lite glass.

Fig. 4. Leaf of *Ipomoea Batatas* unrayed.

Fig. 5. Leaf of *Ipomoea Batatas* rayed for seven weeks at 100 inches from the light, using a screen of quartz-lite glass.

Fig. 6. Leaf of *Ipomoea Batatas* rayed at 50 inches from the light without a screen.



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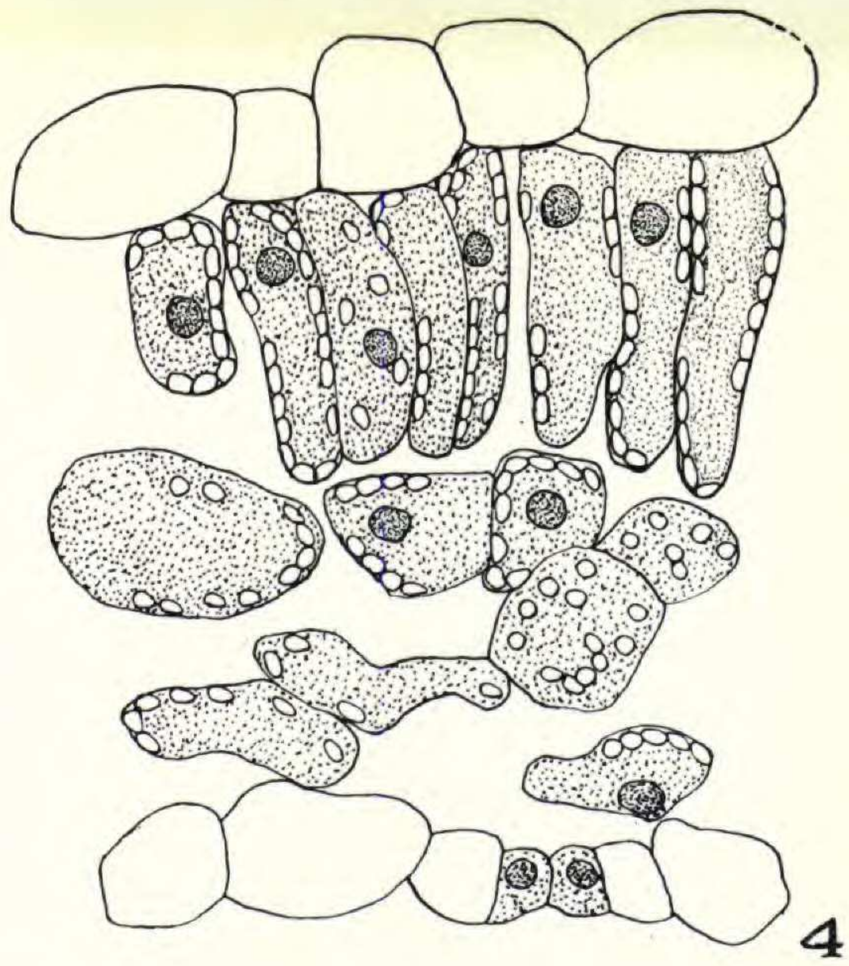

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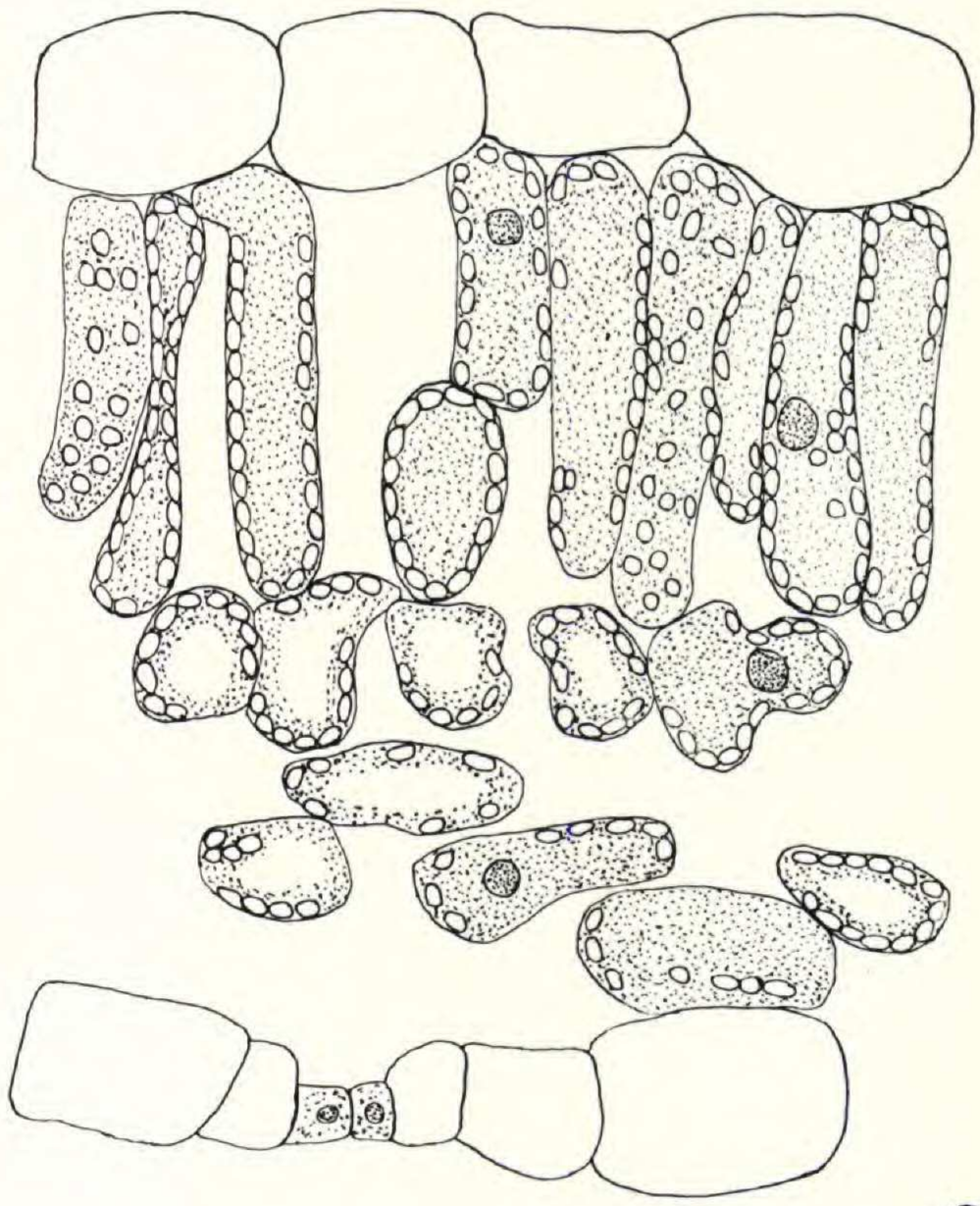

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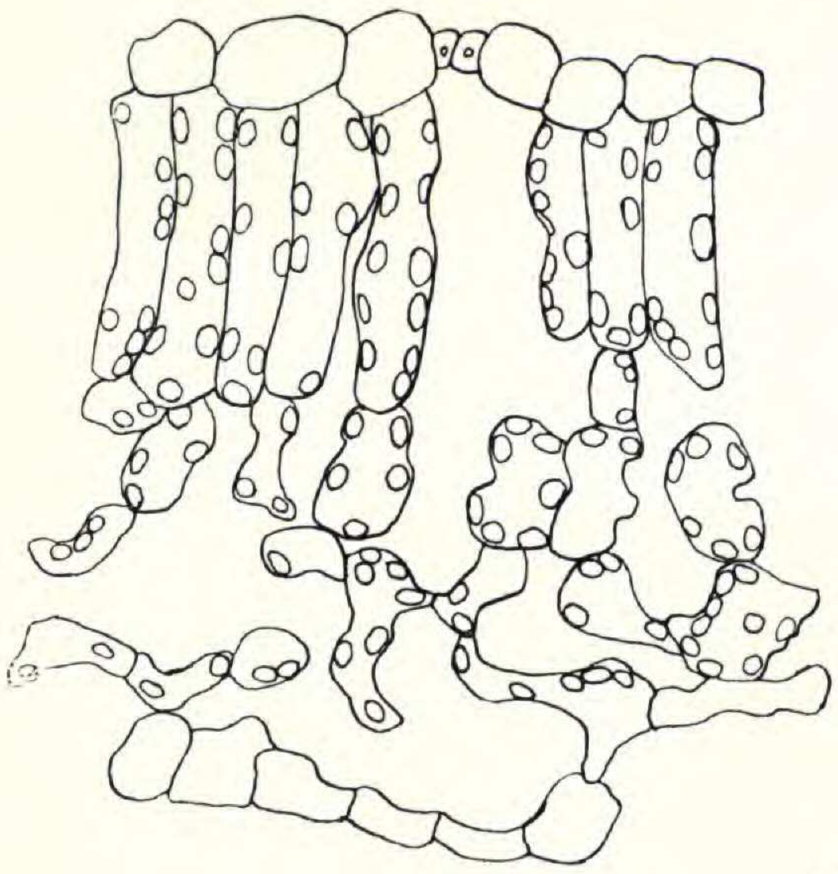

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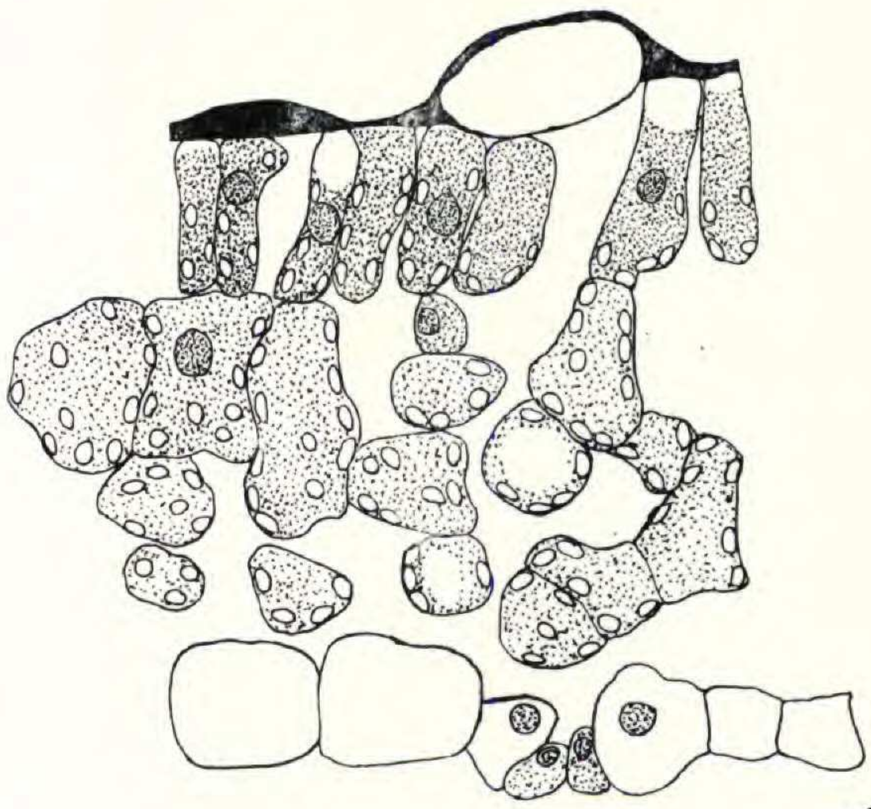


6

ELTINGE—EFFECT OF ULTRA-VIOLET RADIATION

Explanation of Plate

PLATE 30

Camera-lucida drawings of equal magnification, using 4-mm. objective and 10 × eyepiece.

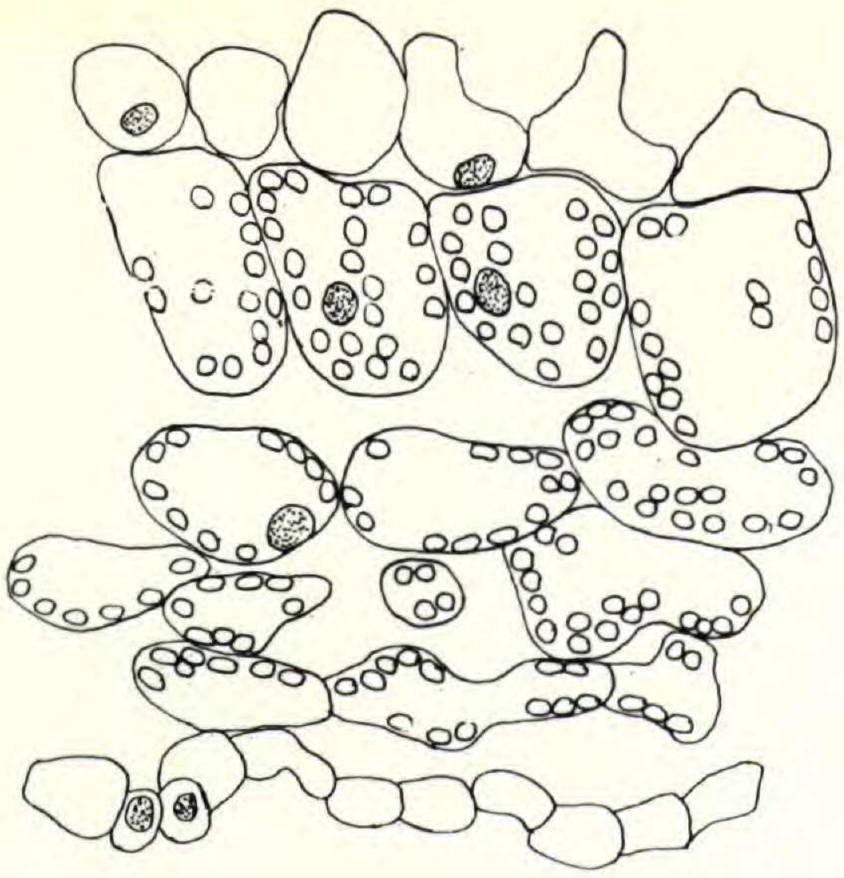
Fig. 1. Leaf of *Coleus Blumei* var. *Verschaffeltii* rayed for seven weeks at 50 inches from the light, using a screen of vita glass.

Fig. 2. Leaf of *Coleus Blumei* var. *Verschaffeltii* rayed for seven weeks at 100 inches from the light, using a screen of vita glass.

Fig. 3. Leaf of *Coleus Blumei* var. *Verschaffeltii* not rayed.

Fig. 4. Leaf of *Coleus Blumei* var. *Verschaffeltii* rayed for seven weeks at 50 inches from the light, using a screen of quartz-lite glass.

Fig. 5. Leaf of *Coleus Blumei* var. *Verschaffeltii* rayed for seven weeks at 100 inches from the light, using a screen of quartz-lite glass.



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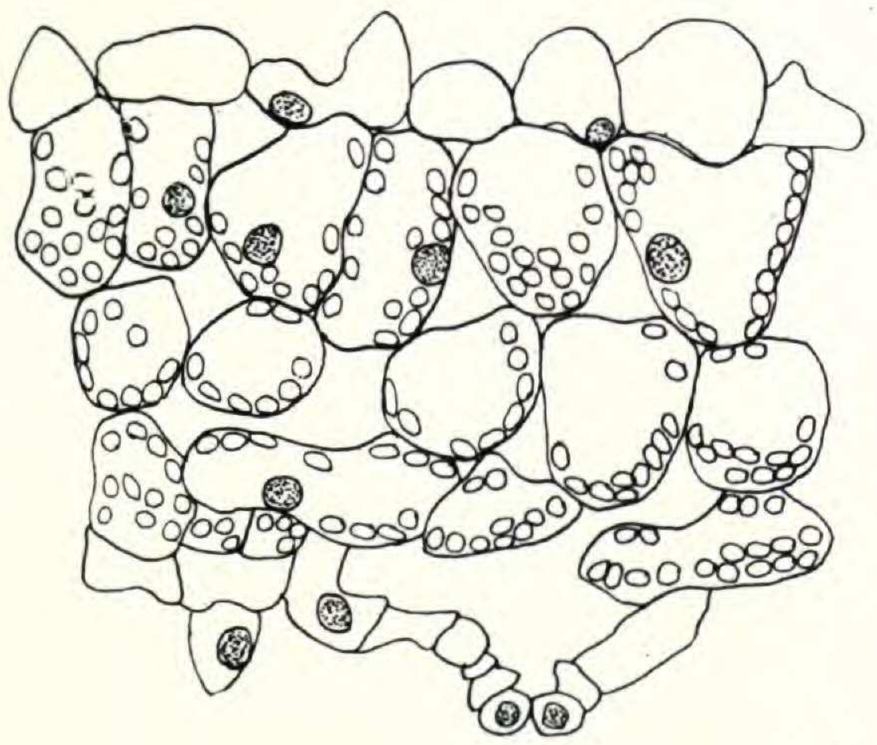

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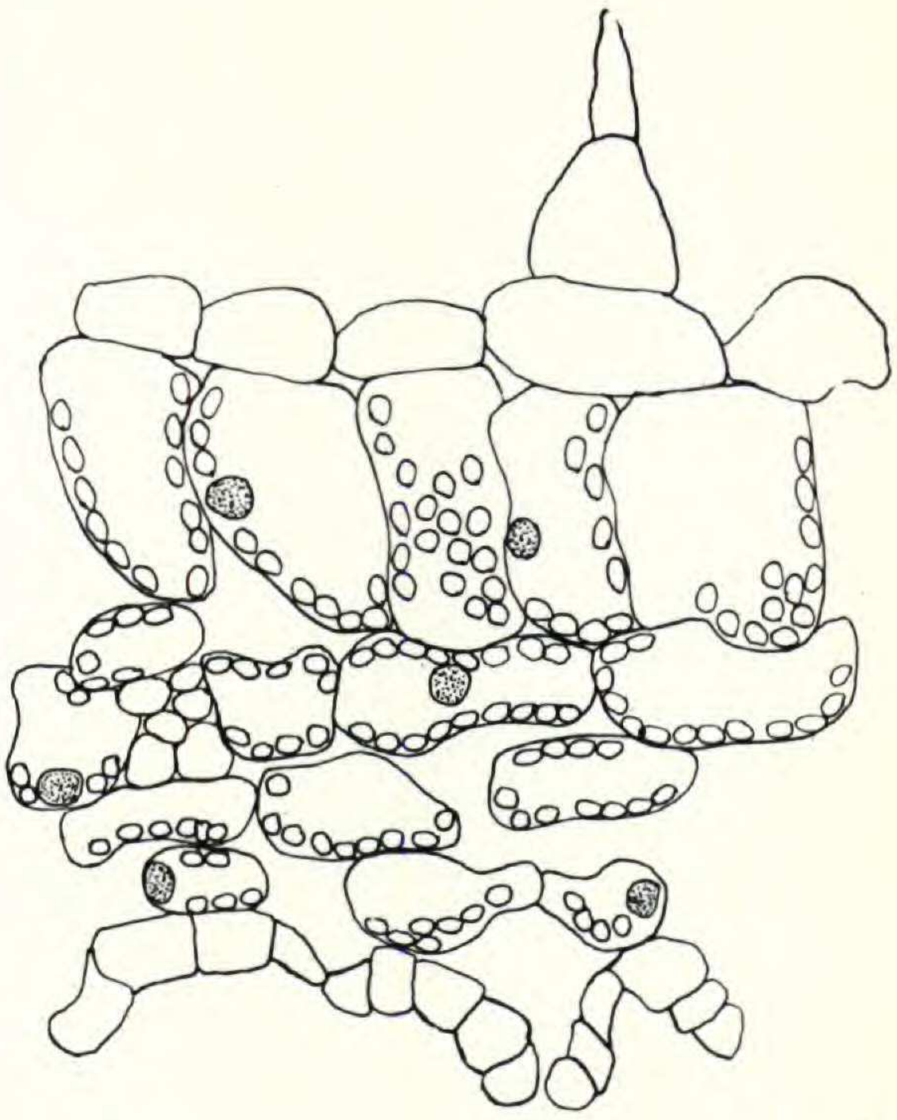

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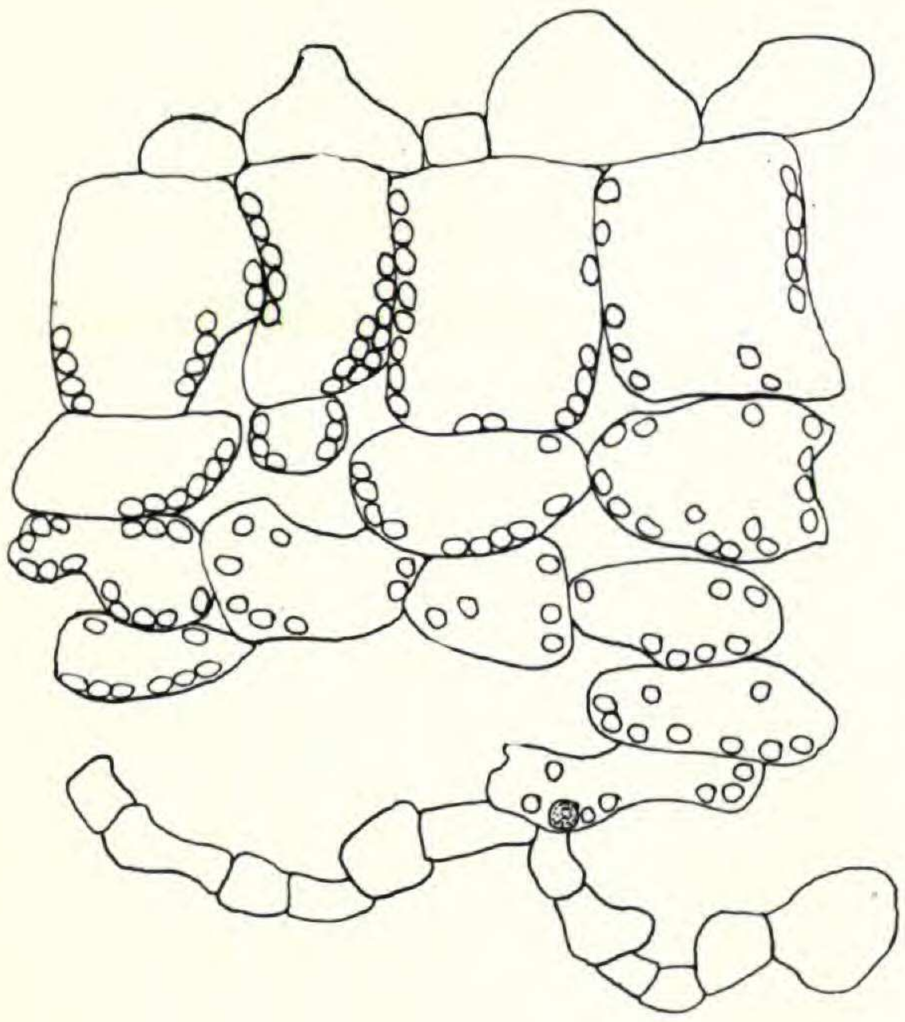

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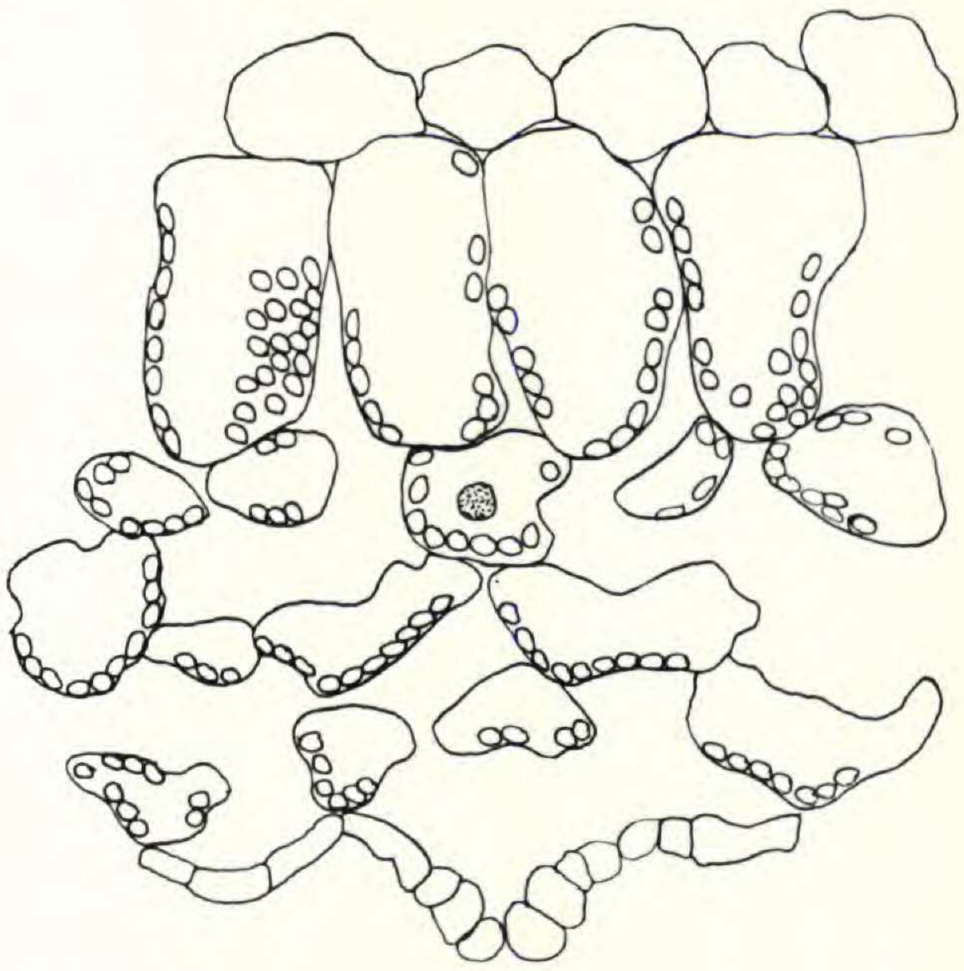


5

ELTINGE—EFFECT OF ULTRA-VIOLET RADIATION

Explanation of Plate

PLATE 31

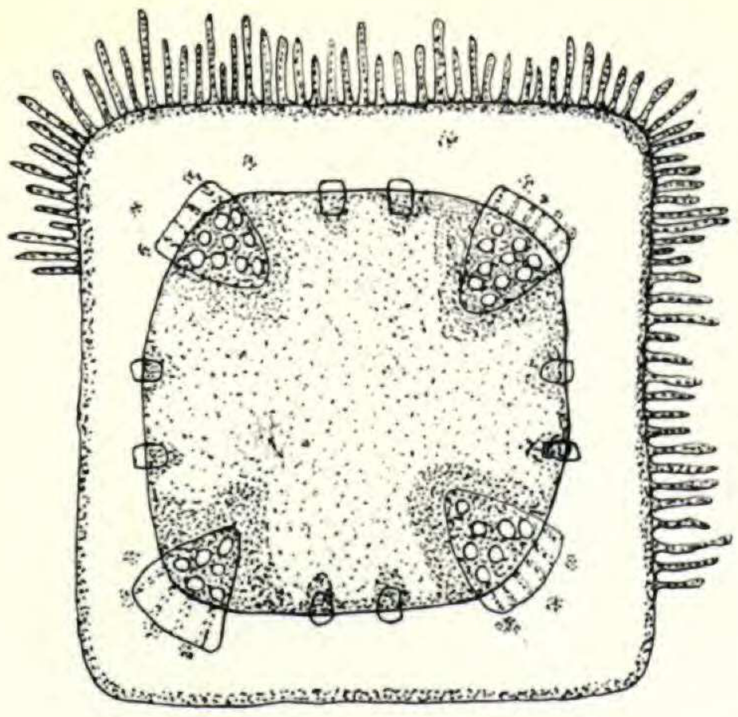
Fig. 1. Diagram of the cross-section of a stem of *Coleus Blumei*, the stippling indicating the normal distribution of red color.

Fig. 2. Diagram of the cross-section of a stem of *Coleus Blumei*, showing the distribution of red color at the end of the fifth raying at 50 inches from the light without a screen.

Fig. 3. Diagram of the cross-section of a stem of *Coleus Blumei*, showing the distribution of red color at the end of the tenth raying at 50 inches from the light without a screen.

Fig. 4. Cross-section of a leaf of *Coleus Blumei*, showing normal distribution of red color.

Fig. 5. Cross-section of a leaf of *Coleus Blumei*, showing the distribution of red color after ten rayings at 50 inches from the light without a screen. Drawn to the same scale as fig. 4.



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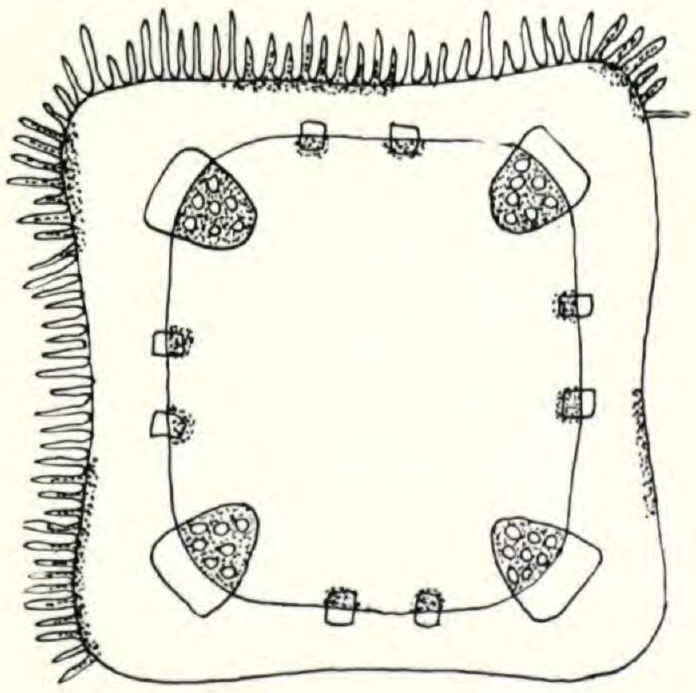

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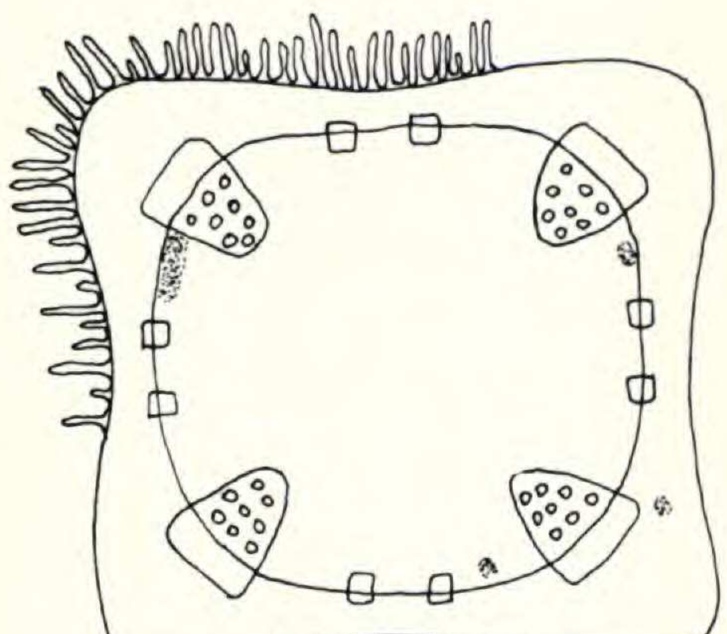

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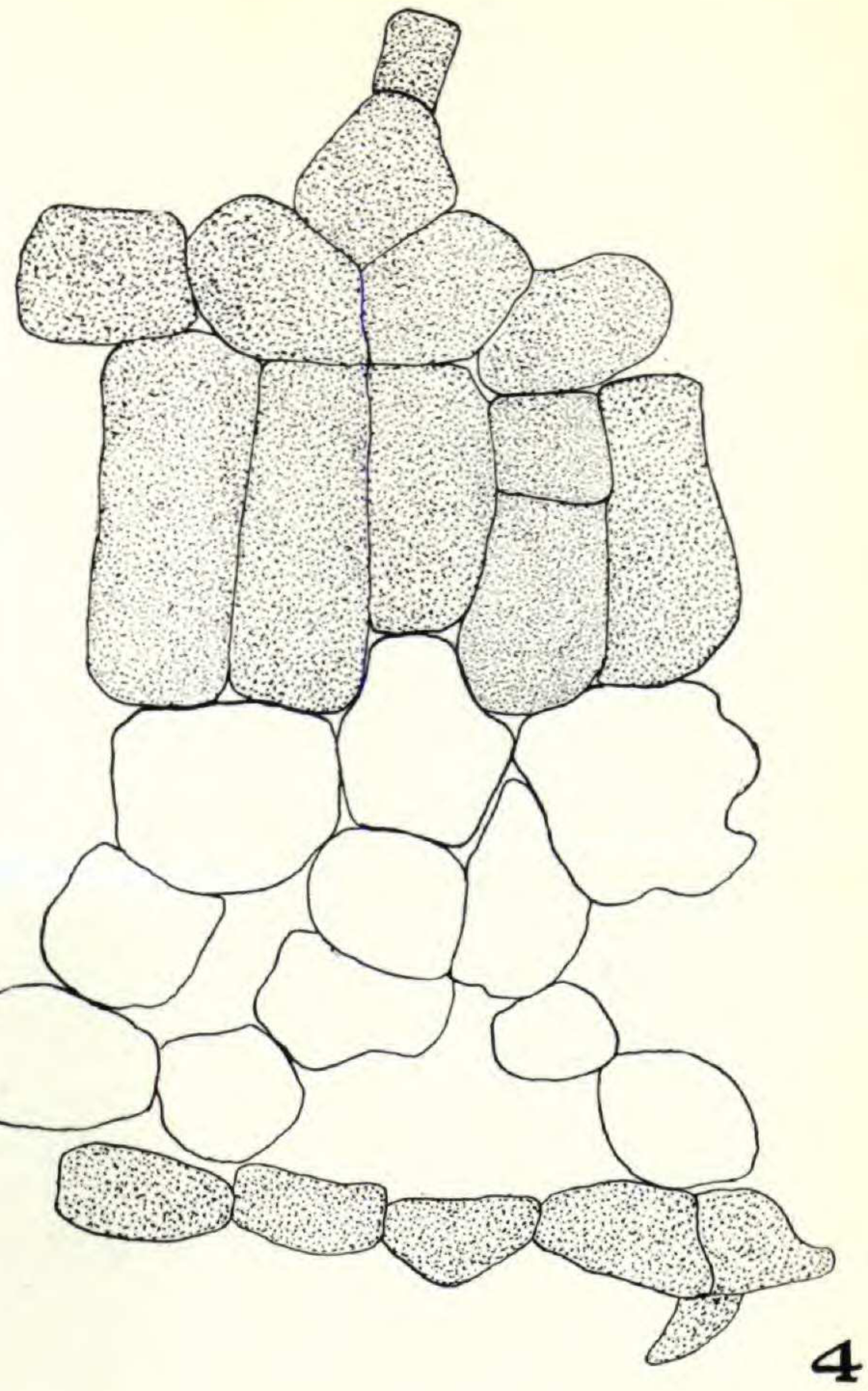

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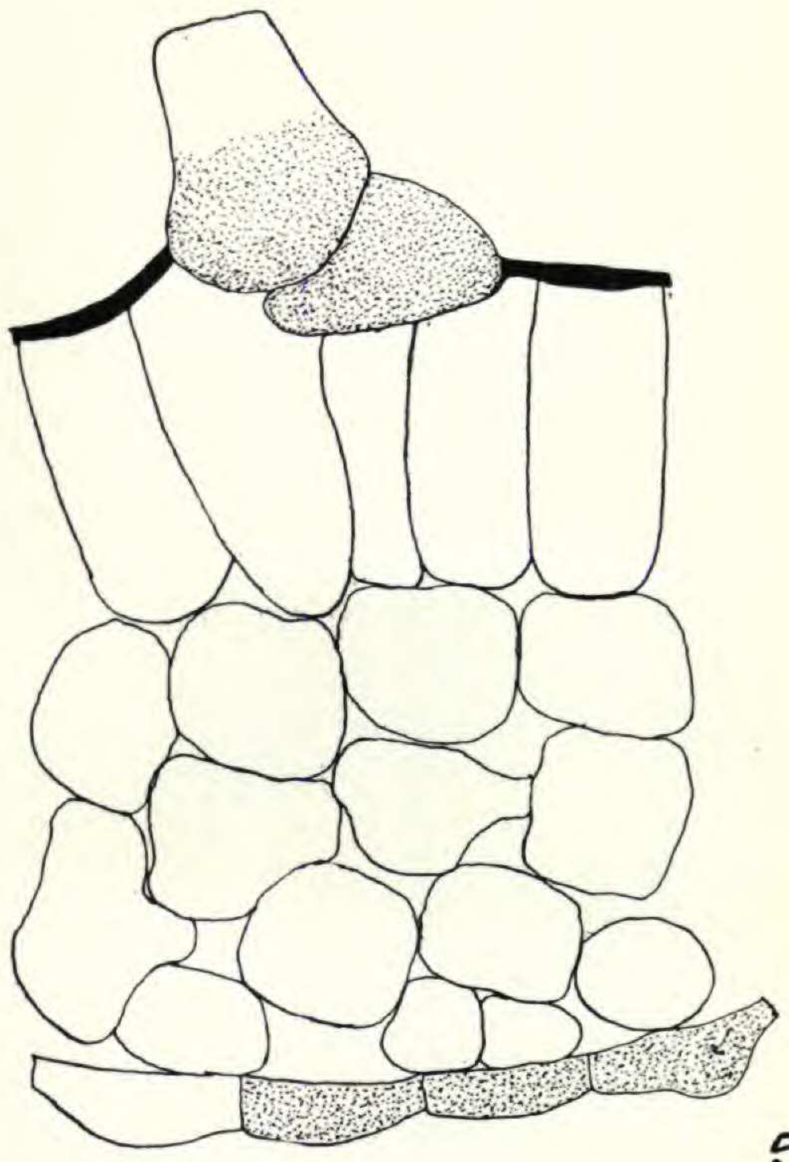


5

Explanation of Plate

PLATE 32

Camera-lucida drawings of equal magnification, using a 4-mm. objective and 10 × eyepiece.

Fig. 1. Leaf of *Zea Mays* unrayed.

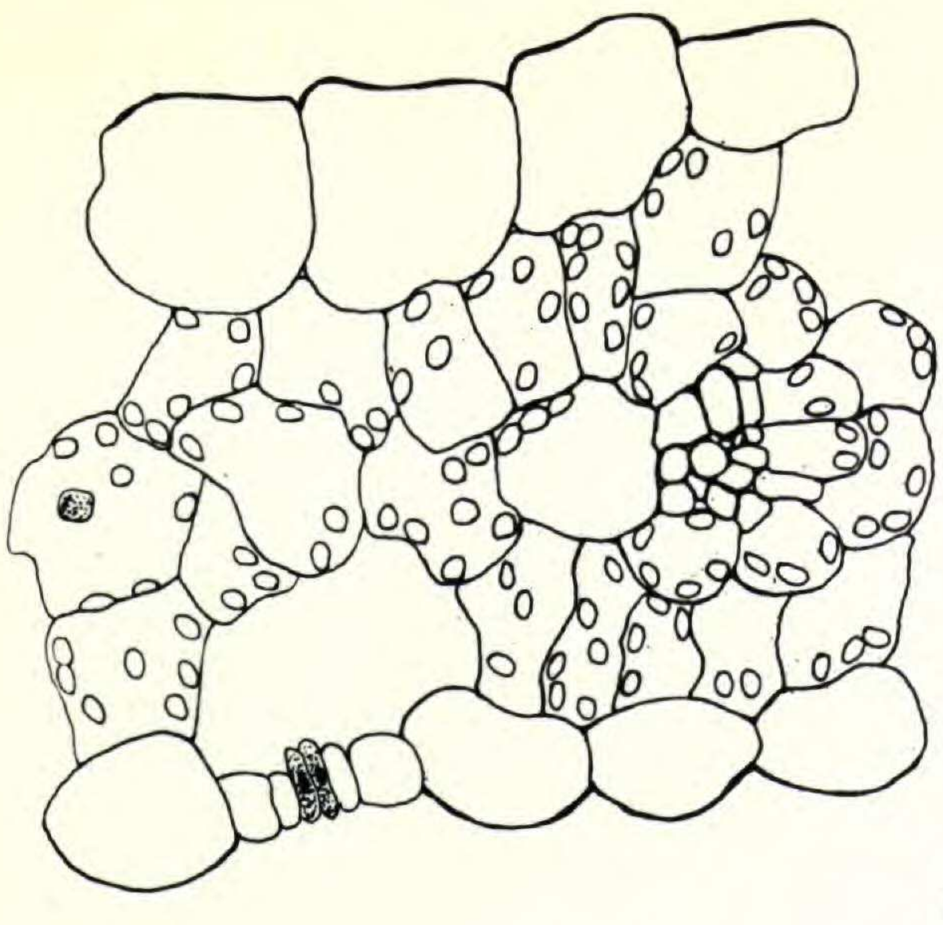
Fig. 2. Leaf of *Zea Mays* rayed for seven weeks at 50 inches from the light, using a screen of vita glass.

Fig. 3. Leaf of *Zea Mays* rayed for seven weeks at 50 inches from the light, using a screen of quartz-lite glass.

Fig. 4. Leaf of *Zea Mays* rayed for seven weeks at 100 inches from the light, using a screen of quartz-lite glass.

Fig. 5. Leaf of *Zea Mays* rayed at 100 inches from the light for seven weeks, using a screen of vita glass.

Fig. 6. Leaf of *Zea Mays* rayed for seven weeks at 100 inches from the light, using no screen.



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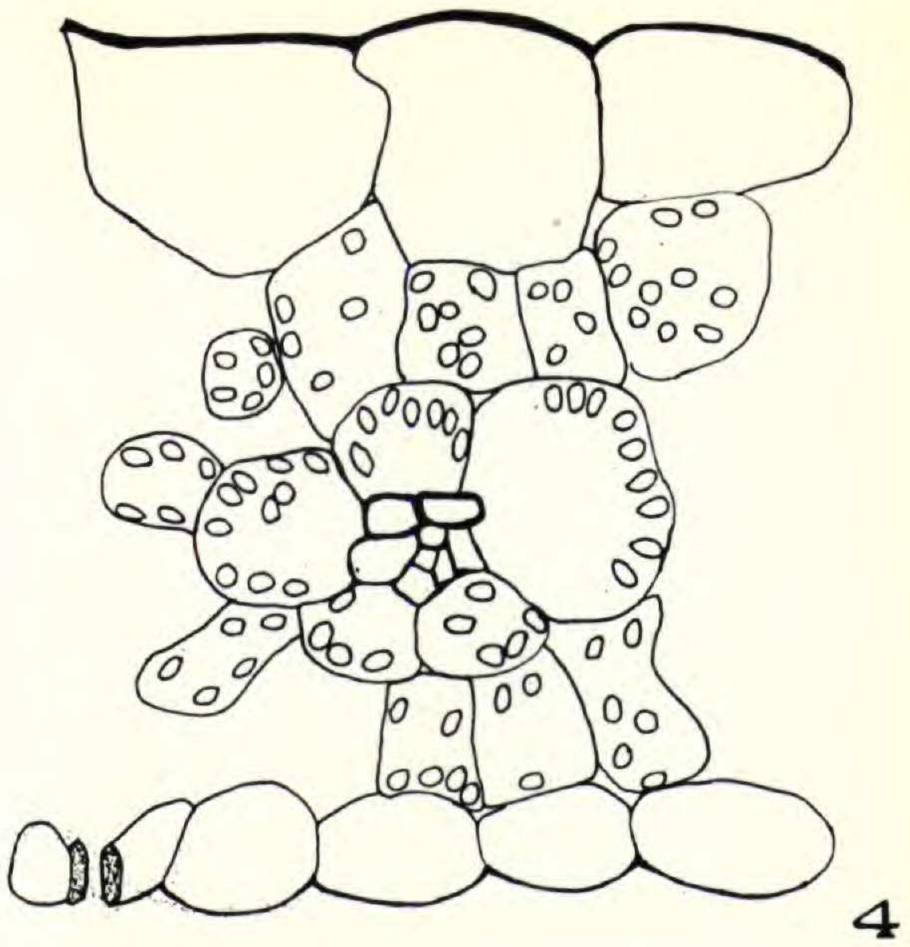

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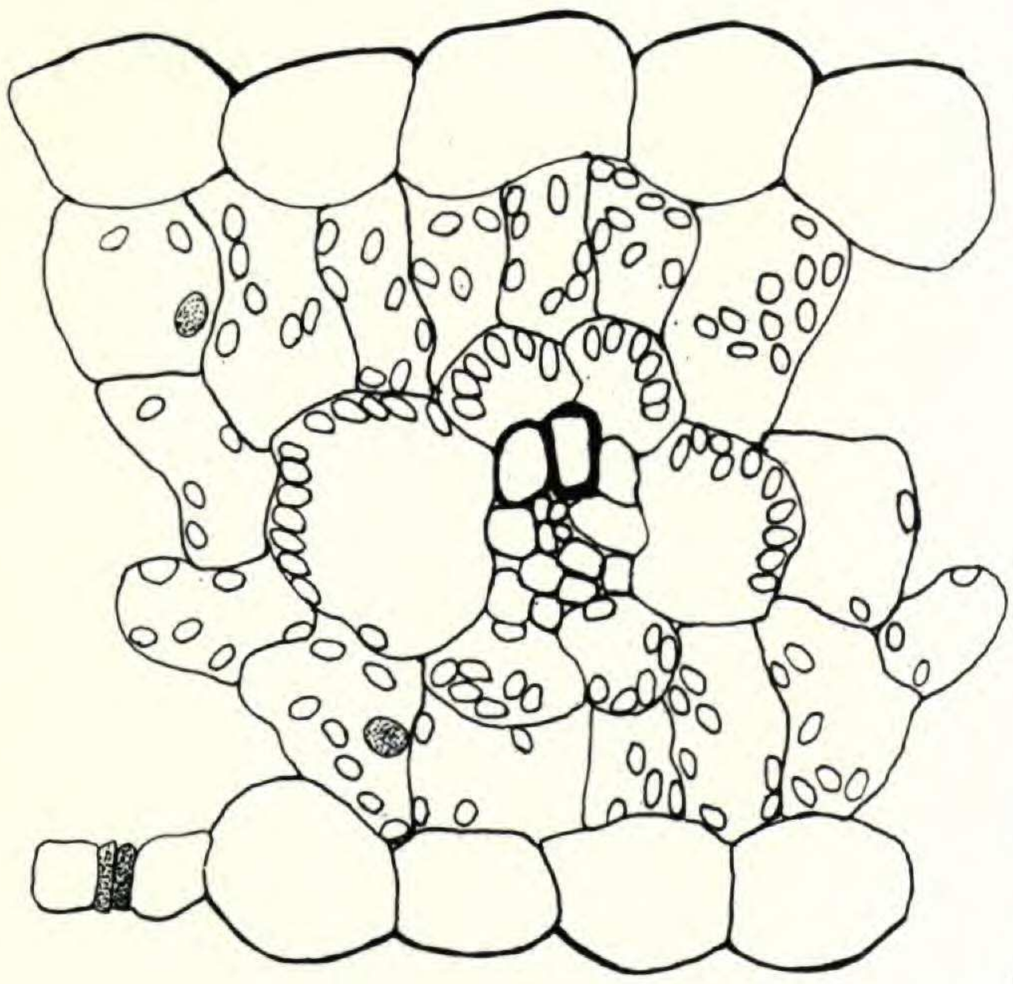

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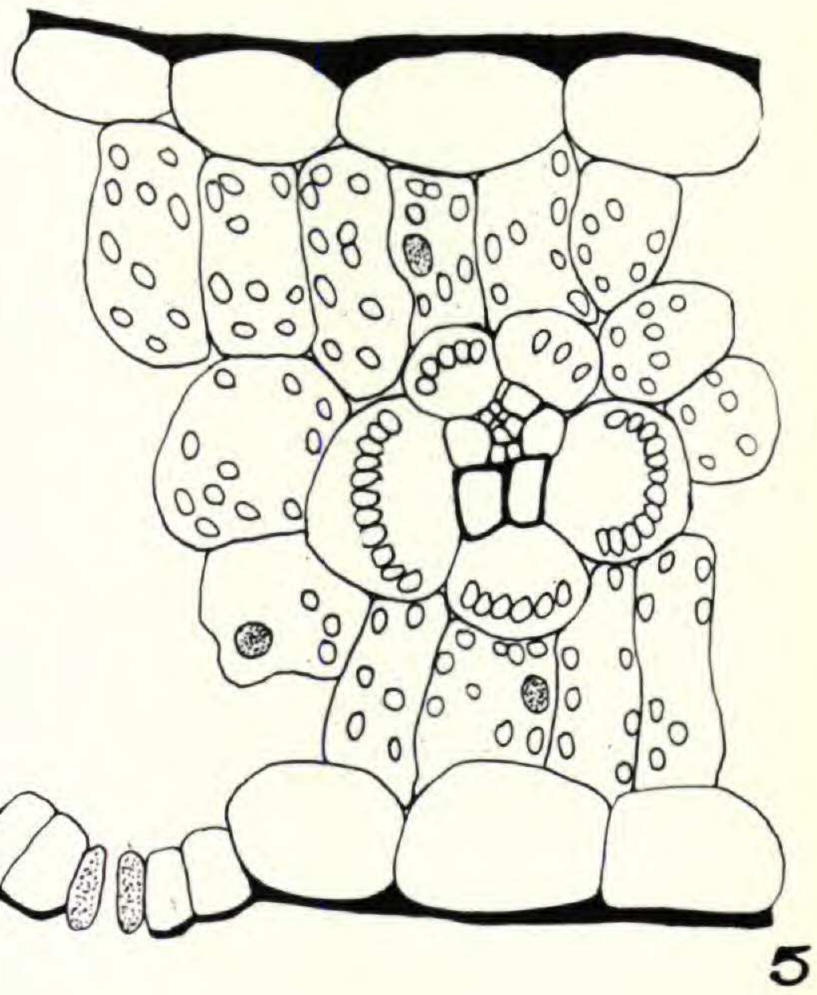

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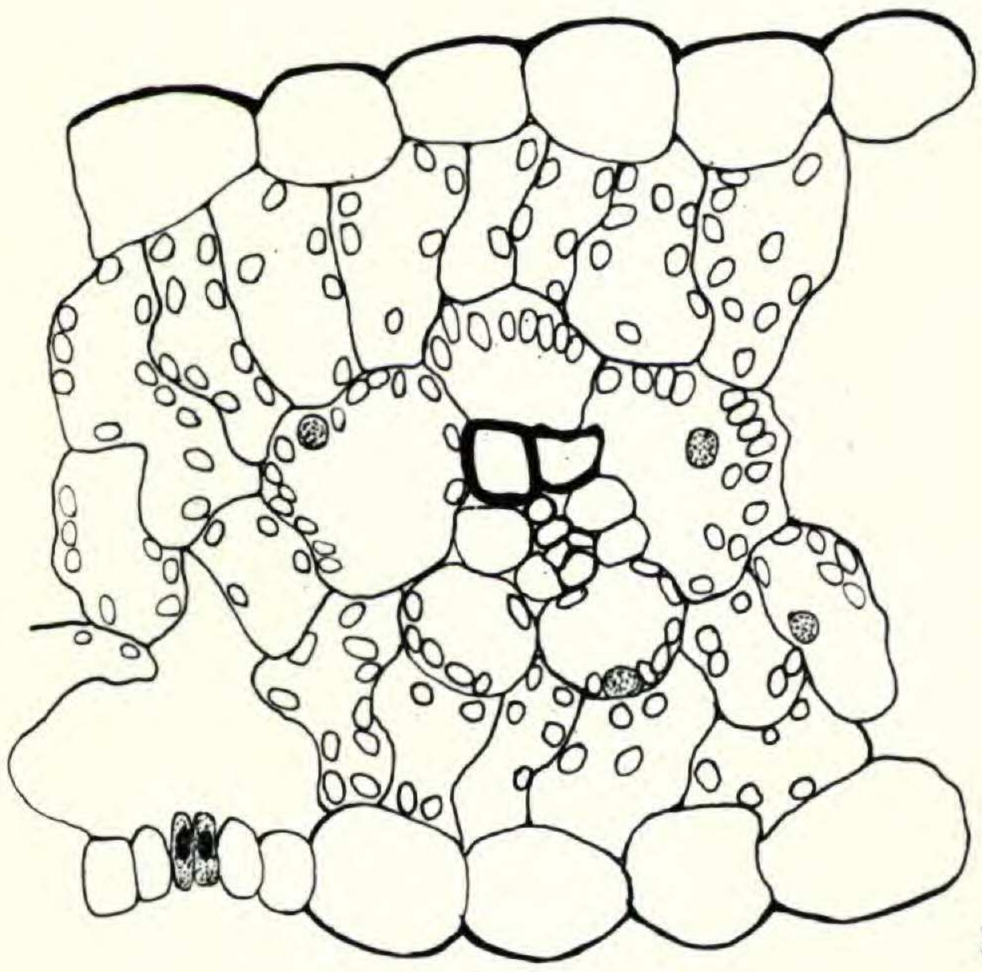

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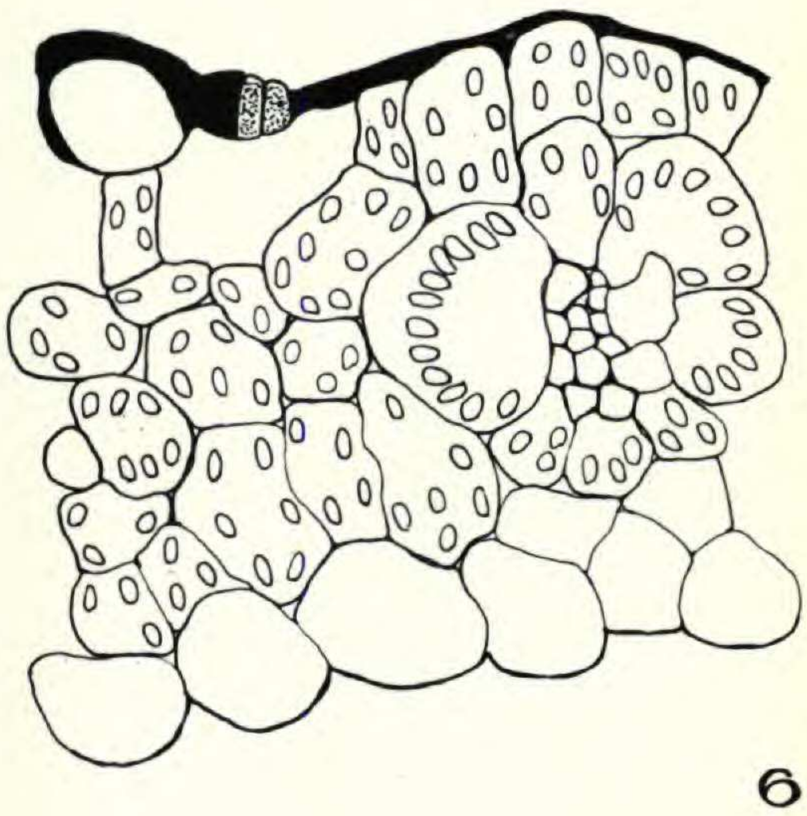

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ELTINGE—EFFECT OF ULTRA-VIOLET RADIATION

Explanation of Plate

PLATE 33

Camera-lucida drawings of equal magnification, using 16-mm. objective and 10 × eyepiece. Corresponding bundles were used in all cases (sixth bundle from the epidermis).

Fig. 1. Cross-section of a fibrovascular bundle of *Zea Mays* from an unrayed stem.

Fig. 2. Cross-section of a fibrovascular bundle of *Zea Mays* from a stem rayed for seven weeks at 50 inches from the light, using a screen of quartz-lite glass.

Fig. 3. Cross-section of a fibrovascular bundle of *Zea Mays* from a stem rayed for seven weeks at 50 inches from the light, using a screen of vita glass.

Fig. 4. Cross-section of a fibrovascular bundle of *Zea Mays* from a stem rayed for seven weeks at 100 inches from the light, using a screen of vita glass.

Fig. 5. The amount of cortex present in a stem of *Zea Mays* rayed for seven weeks at 50 inches from the light, using a screen of quartz-lite glass.

Fig. 6. The amount of cortex present in a stem of *Zea Mays* rayed for seven weeks at 50 inches from the light, using a screen of vita glass.

Fig. 7. The amount of cortex present in a stem of *Zea Mays* rayed for seven weeks at 100 inches from the light, using a screen of vita glass.

Fig. 8. The amount of cortex present in an unrayed stem of *Zea Mays*.